~~2nd Copy~~

VOLUME I. JANUARY, 1894. NUMBER I.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN

2nd Copy

Prospectus

The Electro-therapeutical Laboratory of the Department of Medicine and Surgery of the University of Michigan has been in existence thirteen years, the idea having originated with Prof. John W. Langley then professor of general chemistry and physics. It is, as far as we know, unique, as a feature in medical instruction in this country. Since its introduction as a part of the course of medical instruction in this University, chairs of electro-therapeutics have been established in many other medical colleges in the United States, but the opportunity is not afforded the student elsewhere to become personally familiar with the appliances used in electro-therapeutics by constructing them out of raw material, studying their modes of generating, modifying and controlling electricity and observing the physiological and therapeutical effects they produce. So great is the advantage of this method of instruction in preparation for work so largely technical and so important as a therapeutic aid that we feel constrained to adopt some means for giving greater publicity to what has already been done and is being done here on this plan of instruction, and endeavor to show by an exhibition of the practical work-

ings of this laboratory that medical science will profit largely if similar laboratories should be created in connection with other medical schools.

Although the primary purpose of such laboratories should be to instruct students in the various modes of generating and applying electricity to the body for the amelioration or cure of disease, they may likewise be made the source of more exact knowledge for the practitioner engaged in this branch of therapeutics by undertaking comparative tests of instruments designed for his use and determining in an unbiased manner their relative efficiency and also by subjecting to critical investigation with the aid of instruments of precision the various theories of physiological action which underlie the present practice of electro-therapeutics with the view of testing their soundness and establishing greater simplicity and uniformity in the methods of application.

It is the firm belief of many who have had long experience in electro-therapeutic practice that electric energy is capable of service in the hands of the physician and surgeon that cannot be so well performed, if at all, by any other agent. It is not, however, a "cure all" and the limitations of its efficiency in producing changes in the animal organism need to be sharply defined. This is proper work for the laboratory. The physical and physiological problems suggested can here be worked out under conditions similar to those which are required in the hospital or the physician's office and with attention to details of observation which are there seldom possible.

This method of instruction and much of this character of investigation has been carried on in this laboratory for some time and the opinion is entertained by those in charge that the medical profession would be profited and the science of electro-therapeutics advanced by the occasional putting forth of a bulletin of information of what is being done not only here but elsewhere.

The chief purposes of this bulletin will be

To advocate better methods of instruction for medical students in electro-therapeutics,

To publish explanations and tests of efficiency of electro-therapeutic apparatus.

To publish the results of experiments physical, physiological and therapeutical made with the view of advancing the science of electro-therapeutics.

To explain the nature of electric action derived from different sources, as primary batteries, secondary batteries, induction coils, dynamos, static machines, etc., and to indicate the physiological action of each and the therapeutical work to which it is best adapted.

To answer the queries, to a limited extent, of those members of the profession seeking special information.

It is our present plan to issue the numbers of this bulletin quarterly, and in order that the expense attending it may be met, in part at least, a subscription price of one dollar a year is fixed. The numbers will be sent, as issued, to anyone who may choose to transmit this amount to the publishers for this purpose.

REGISTER PUBLISHING CO.,

Ann Arbor, Michigan.

The Present Course of Instruction in the Laboratory

The work in the laboratory of electro-therapeutics is arranged with a view of making the student familiar with the practical points that are likely to arise in the use of machines for generating static electricity, continuous, interrupted, alternating and other kinds of currents used for medical purposes. In order to accomplish this, each student is required to construct (from the raw material, as far as practicable) his own batteries and other appliances for generating such currents and for applying them to the body. And where for any reason such appliances are furnished ready made, they are constructed in the simplest form consistent with efficiency, and their parts left bare for inspection, if possible, so that their action is not

obscured and the principle lost sight of through any mystery of mechanism.

The course begins by testing the strength of currents generated by the action of dilute acids on various dissimilar metals, by which the student finds the position which the various metals occupy in the 'contact series,' ahd thus learns to choose those which for reasons of efficiency and economy are best adapted for the requirements of electro-therapeutics. Zinc and carbon being found to meet these conditions, experiments are then made to illustrate the necessity for amalgamating the zincs, and avoiding polarization in battery action so as to secure a constant and unvarying current. The form of cell which best meets the conditions of constancy, combined with the highest electromotive force is then determined by tests of a large number of batteries, double and single fluid and dry, as to their chemical reactions, polarization and depolarizing capacity, local action, internal resistance, etc. Following these tests, the students make for their further work with continuous currents, zinc and carbon bichromate eight-cell experimental batteries, which are required to register at least sixteen volts as a test of their accuracy in construction. After determining the electromotive force and the internal resistance of these experimental batteries, problems for determining strength of currents with known resistances are solved and then, the current being known from a galvanometer reading, a series of problems is given to determine unknown resistances; after which the body resistances are tested by introducing various parts of the body into the circuit. The student constructs his own electrodes for applying the current to the body. Experiments in divided currents, shunt circuits and joint resistances are then undertaken with the view of illustrating the conditions met with in the action of currents when traversing the various tissues of the body.

The student having thus become practically familiar with the phenomena attending continuous current generation and conduction, and the conditions that attend them, the action of a continuous current in producing electrolysis is then deter-

mined by actual test on a variety of *ions*. Animal tissues are next subjected to electrolytic decomposition and the polar action demonstrated. At this point in the course some clinical cases are usually operated upon illustrating the therapeutic application of electrolytic action and the reasons for the choice of the cathode or anode in particular cases.

The action of the continuous current in modifying the phenomena of osmosis is then demonstrated by experiments, following which the cataphoric action of the current is shown by introducing coloring matters and medicinal agents through the skin by means of it.

The batteries are next arranged for generating a current suitable for heating a cautery, and the conditions necessary tor successful galvano-cautery work are experimentally studied. As a part of this work, each student is required to make a cautery that will stand the test of a current of eight amperes.

Since accumulators or secondary or storage batteries are now so frequently used for the purpose of heating cauteries and lighting exploring lamps, the principles of the storage battery are taught by requiring each student to construct one out of simple materials.

Induction currents are next considered and the principle of magneto-electric and induction machines is inculcated by the construction of temporary magnets and a study of the phenomena they exhibit in taking on and parting with their magnetism. An induction coil generating primary and secondary induced currents similar to the ordinary medical induction apparatus is put in the hands of each student. It is so constructed that its mechanism can be readily seen, and the courses of the various currents traced. With this apparatus experiments are conducted upon the body, illustrating the physiological effects of interrupted currents of varying degrees of electromotive force on tissue action.

The laboratory contains models of the various forms of dynamos employed for electric lighting, supplying power for motors and other purposes, and as these currents are utilized for therapeutic work by many surgeons, physicians and den-

tists the student is made familiar with their action and the character of current generated by each.

Frictional electricity is illustrated by several forms of static machines, and the student is instructed how to operate them for therapeutic applications.

This course of laboratory instruction covers a period of six weeks and is preliminary to a hospital course, in which each student has an opportunity to extend and apply his electro-therapeutic knowledge in the treatment of disease.

Practitioner's Course

Many physicians who would gladly avail themselves of the advantages afforded by electricity in the treatment of disease hesitate to make use of it because they lack just such training as this laboratory is designed to furnish. In order to meet this need the laboratory of electro-therapeutics in common with the other laboratories connected with the Department of Medicine and Surgery of the University offers special courses to graduates in medicine who desire to fit themselves for work in electro-therapeutics. Practitioners who can arrange to spend a month or six weeks in pursuing one or more such special courses will find the facilities for instruction and illustration well adapted to their needs. The Regents have fixed a uniform fee of ten dollars for these "graduate courses" as they are termed, and this amount covers the entire cost of one such course except what may be incurred for material used up or destroyed in experiments. Physicians who wish to take such a course in special preparation for electro-therapeutics can apply at any time during the college year which lasts from October 1st to June 30th.

Tests of Efficiency of Electro-Therapeutical Apparatus.

Electro-therapeutics can progress as a science only in proportion as those practicing it are able to compare methods and results. The instruments employed, if not identical in structure and capacity, must be so far understood in their action by all electro-therapeutists that the work done by any combination of apparatus can be estimated at its real value. Electric energy employed for therapeutic purposes should be measured with the same care and accuracy as when applied to mechanics or chemistry. In the use of continuous currents, or galvanism, the electro-motive force, the quantity of current, and the current density are each important elements in the application, and, if what is claimed for their action by one operator is to be verified by another he must be able to arrange his apparatus so as to secure indentity in these conditions. This does not mean that he must make use of identically the same instruments or those of the same manufacturer, but, that in his attempt to secure the same or verify the results reported by another he must have a corresponding voltage, the same current and similar electrodes. This of necessity requires standard instruments of measurement for electro-motive force and current, and electrodes the size, shape and material of which should be the same.

But back of the measurement of electro-motive force of continuous currents the operator is interested to know what is the most satisfactory source from which to derive electric energy for continuous current work. The sources now being utilized are many, such as primary batteries, secondary batteries, and continuous current dynamos used for electric lighting, propelling street-cars and distributing power for other purposes. The dynamo current is by far the most convenient when the treatment can be given in the physician's office, but only the favored few have access as yet to such sources for continuous currents, and secondary batteries do not meet the

need for all kinds of therapeutic work to which continuous currents are adapted. So that for years to come the large majority of physicians, if they wish to employ electricity in their practice, must depend upon some form of primary battery as a source of electro-motive force.

It is desirable, therefore, and necessary, for the reasons above stated, that such forms of primary batteries as are most commonly used by physicians should be compared with each other and their relative efficiency as to voltage constancy and durability determined when subjected to such action as is required of them in electro-therapeutics. Tests of single cells, according to the method employed by the manufacturer of these batteries, or such as are reported from physical laboratories, are of very little service to the electro-therapeutist. What he wishes to know is, how will a number of such cells, coupled in series or in multiple, act when subjected to the demands of electro-therapeutic work.

By far the largest share of benefit credited at the present time to electricity as a therapeutic agent is derived from continuous currents or galvanism. It seemed proper, therefore, that among the first investigations made in this laboratory should be some to determine the relative efficiency of such primary batteries as are more commonly used by physicians, and of others that give promise of being equal to or superior to those now in use. And first we have given our attention in these investigations to that class of primary batteries that are used for stationary plants for office work, with continuous currents.

Experience has taught us that for general office work with continuous currents an electro-motive force of from 50 to 75 volts is required. It is desirable that this voltage should be uniform, with as little fluctuation as possible. The batteries should be so constructed as to require the least possible attention, and, other things being equal, those which last the longest time without renewal would prove the most service able.

In judging of the comparative worth of such batteries,

therefore, for electro-therapeutic purposes the main features to be considered are

Amount of electro-motive force, constancy of electromotive force, ease of maintenance, durability.

Primary Battery Tests.

The groups of cells whose action is reported upon below were sent to the laboratory by the manufacturers to be tested at the suggestion of the Council of the American Electro-Therapeutic Association. The cells were set up and arranged in series strictly in accordance with the directions which accompanied them. The tests are designed to determine the efficiency of these cells as a source of continuous currents for therapeutic purposes on the basis of the requirements set forth in the preceding article. The resistances introduced into the circuit generated by each battery of cells are such resistances as would be met with in the ordinary practice of electro-therapeutics. At the beginning of each test the circuit is closed, the resistance and voltmeter being in circuit, and the voltage noted. This reading is the "initial voltage" recorded. The milliamperemeter is then made to take the place of the voltmeter and remains in circuit during the time allotted to the test, which is that ordinarily consumed in treatments for therapeutic purposes. The current is recorded in milliamperes, and at the close of the test the voltage is again noted.

It is designed that these batteries shall do the amount of work daily that they would in all probability be subjected to if they were actually on duty in a physician's office, and it is our purpose to treat them while undergoing these tests in all respects as they would be handled by a careful and conscientious electro-therapeutist. Every cell is in sight and the condition of the fluid, elements and connections can be seen at a glance.

The durability of these cells can be determined only by running them down, and this in case of some of them, at least, will require many months. Subsequent reports will be made

from time to time of their action, and any comments on their relative virtues will be postponed until the tests are completed.

These groups of batteries are composed of cells too large in size to be used in the manufacture of portable batteries, and are suitable only for stationary batteries for office work. They are all, with the exception of the Partz No. 3, some modification of the original Leclanche' cell—with zinc and carbon elements immersed in a solution of ammonium chloride, or *sal ammoniac,*—each form being constructed with the view of diminishing internal resistance and either preventing or retarding polarization. The success with which these obstacles have been met in each form of cell here represented will appear as the tests progress.

A group of fifty "Vole" cells has been recently added to this series and will be included in the second report which will appear in the July number of the BULLETIN.

FIRST REPORT.

Battery.	Date.	Initial Voltage.	Resistance.	Current.	Time.	Final Voltage.	Volt-Meter. M. A. Meter.	Remarks.
Partz ac'd gravity.	7-22-93	60	2600	.027	30 m	53	Weston.	(30 Cells).
"	8-15-93	57.6	1600	.0385	15 "	56.6	"	"
"	8-16-93	57.5	1075	.055	15 "	56	"	"
"	8-17-93	57.4	1224.92	.057	10 "	56.1	"	"
"	8-18-93	57.3	2450.4	.025	20 "	56.4	"	"
"	8-22-93	57.1	100	.340	10 "	53.2	"	"
"	8-24-93	56.4	2250.47	.025	10 "	56.6	"	" (Rise in
					"		"	E. M. F.)
"	8-26-93	56.6	4700.87	.012	5 "	56.3	"	"
"	8-29-93	56 3	1100.0	.0045	20 "	56.1	"	"
"	8-30-93	56.5	2000	.027	15 "	55.3	"	"
"	9- 1-93	56.2	2000	.028	15 "	55	"	"
Partz No. 5	7-24-93	53	2400		15 "	49	"	(38 Cells.)
"	8-15-93	69.8	1600.2	.044	15 "	62	"	(50 Cells.)
"	8-16-93	69	3100	.016	10 "	67.5	"	"
"	8-17-93	69	1225	.004	3 "	69	"	"
"	"	69	1225	.0445	10 "	61.3	"	"
"	8-18-93	68.8	2450	.027	20 "	60	"	"
"	8-22-93	66.4	100	.270	10 "	45	"	"
"	8-24-93	64.6	2250.68	.0195	10 "	52.6	"	"
"	8-26-93	66	4700.83	.012	5 "	60.1	"	"
"	8-29-93	66	11000	.0055	20 "	61	"	"
"	8-30-93	64	2000	.031	15 "	54	"	"
"	9- 1-93	63.8	2000	.0335	15 "	52.2	"	"

(Continued.)

(First Report Continued.)

Battery.	Date.	Initial Voltage.	Resistance.	Current.	Time.	Final Voltage.	Volt-Meter. M. A. Meter.	Remarks.
Laclede.	7–12–93	72.5	1000	.065	10 "		Weston.	(50 Cells.)
"	7–17–93	61.5	2600	.025	10 "	60	"	"
"	"	68	140	.400	10 "	59	"	"
"	7–24–93	67	1100		15 "	64	"	"
"	7–28–93	67	1800	.038	30 "	50	"	"
"	8–15–93	66.2	1600.1	.0375	15 "	64.5	"	"
"	8–16–93	66	1075	.056	15 "	63.2	"	"
"	8–17–93	65.9	1225	.049	10 "	63	"	"
"	8–18–93	66.4	2450.92	.024	20 "	64.4	"	"
"	8–22–93	65	100	.550	10 "	52	"	"
"	8–24–93	64.5	2250.19	.0175	10 "	62.6	"	"
"	8–26–93	65.4	4700	.011	5 "	64.8	"	"
"	8–29–93	66.3	11000	.005	20 "	65.8	"	"
"	8–30–93	64.4	2000	.031	15 "	62.5	"	"
"	9– 1–93	61.8	2000	.067	15 "	60	"	"
Axo.	7–28–93	75	200		30 "	60	"	"
"	8–15–03	76.4	1600.1	.042	15 "	73.2	"	"
"	8–16–93	76	1075.92	.062	15 "	71	"	"
"	8–17–93	75.8	1224.92	.0645	10 "	71.8	"	"
"	8–18–93	75.6	2450	.0325	20 "	73	"	"
"	8–22–93	76.5	100	.370	10 "	70.1	"	"
"	8–24–93	75	2250.47	.032	10 "	72.2	"	"
"	8–26–93	75.6	4700	.013	5 "	74	"	"
"	8–29–93	75.4	11000	.0055	20 "	74.3	"	"
"	8–30–93	75.3	2000	.033	15 "	72	"	"
"	9– 1–93	75	2000	.035	15 "	74.2	"	"
Fitch.	8–15–93	67.6	1660.1	.038	15 "	63.4	"	"
"	8–16–93	66.4	1075	.067	15 "	64.6	"	"
"	8–17–93	66	1225	.049	10 "	64.6	"	"
"	8–22–93	66.6	2450	.0308	20 "	64	"	"
"	8–22–93	65	100	.500	2 "	61.5	"	"
"	8–24–93	61.5	2250.19	.025	10 "	65 7	"	"
"	8–26–93	67	4700.87	.0165	5 "	66	"	"
"	8–29–93	67.3	11000	.0055	20 "	66.2	"	"
"	8–30–93	66	2000	.031	15 "	62.6	"	"
"	9– 1–93	64.3	2000	.0305	15 "	63	"	"
Law.	7– 8–93	69	1000	.060	10 "		"	"
"	7–15–93	59	2600	.025	12 "	56	"	"
"	7–21–93	59.5	1100	.055	15 "		"	"
"	8–15–93	67.8	1600	.054	15 "	54.5	"	"
"	8–16–93	67	1075	.064	15 "	49.3	"	"
"	8–17–93	66.4	1225	.062	10 "	50.4	"	"
"	8–22–93	63.1	2450.4	.0425	20 "	54	"	"
"	8–22–93	62.4	100	.380	12 "	45.4	"	"
"	8–24–93	65.3	2250.47	.036	10 "	60.8	"	"
"	8–26–93	67	4700	.014	5 "	61	"	"
"	8–29–93	67.3	11000	.0075	20 "	61.8	"	"
"	8–30–93	66.9	2000	.056	15 "	54	"	"
"	9– 1–93	64.6	2000	.035	15 "	60.2	"	"

Production of Alternating Currents by Means of Electro-Static Machines.

BY DR. S. LEDUC,

PROFESSOR OF MEDICAL PHYSICS, SCHOOL OF MEDICINE, NANTES, FRANCE.

(Revue Internationale D'Electrotherapie, September, 1893.)

By means of electro-static machines a variety of alternating currents can be produced for medical uses. It is possible to obtain alternating currents of high teusion and great frequency, which possess analogous if not identical properties to those derived by Nicola Tesla from other methods, and which are capable of manifesting many of the beautiful phenomena with which his experiments have made us familiar, such as luminous conductors, showers of sparks, surface luminations, lighting of lamps within the electric field both by contact and at a distance, etc. In order that such currents may be produced, the static machine should be provided at each pole with a ball exciter, having an insulated handle and with a Leyden jar, the internal surface of which is in connection with the conductor of the machine. If then the external surfaces of the jars are joined by a circuit of great resistance, when the balls of the exciters are separated, a series of sparks pass between them, and the circuit which joins the external surfaces of the jars is traversed by alternating currents of high intensity and great frequency.

Each spark between the exciters is accompanied and followed by variations of potential (electric oscillations) in the conductors of the machine and the internal surfaces of the Leyden jars which are united by them. Each oscillation produces a flow and reflow of electricity in the external surfaces of these jars, and in the circuit connecting them, a circuit which then is traversed by alternating currents of great frequency. If a person is introduced in this circuit he is permeated by these currents. The circuit is formed by two chains attached to the external surfaces of the jars, one being dropped on the floor by its free extremity while the other is

attached to an electrode which can be applied to some part of the body; the circuit is then formed by the two chains, the subject and the floor.

The oscillating magnetic field created around these conductors is so intense that by aid of these currents the nerves can be excited without establishing any connection between the electrode and the machine, and utilizing only the currents induced in the electrode.

This is the best method. To apply it, one chain must be attached to the ground (connected with a water pipe, for example), the other end of the chain being fixed to the electrode, which under these conditions is traversed by alternating induced currents of greater intensity according as it is brought nearer to the conductors of the machine.

Thus the electrization can be accomplished from a distance of .25 to several meters from the conductors, according to the intensity it is desired to employ.

Electrization by the means of such alternating currents can be made:—

First, by placing the subject in the oscillating magnetic field; second, from a distance by sparks; third, by applying the electrode to the skin.

To place the subject in the oscillating magnetic field, put him on an insulated platform, to which attach the chain from the external surface of one jar, the other being fastened to a conductor suspended above the head of the subject. Under these conditions, when the sparks between the conductors are continuous, there is hardly any sensation; but when the sparks become intermittent the sensation is very clearly perceptible, and difficult to define. This sensation is most marked on the head. If the head is a little way from the conductor, the interval becomes luminous with a shower of sparks; if the interval is still less single sparks are produced. This accident is avoided by taking for a conductor, in place of a metal plate, a surface covered with points.

Electrization from a distance gives place to the production of sparks the length of which varies with the potential, that is to say, with the distance between the balls of the exciters.

The sparks with a ball electrode of 36 mm. diameter are always multiple; they cause great pain, make the fibres of the skin contract and produce "goose flesh." It is without doubt that the anæsthesia noticed by d'Arsonval is due to this superficial anæmia.

Oudin and Labbe' published in *Moderne Medecine* a report on the favorable action of sparks on neuralgia. We have also often proved this, but it seems this result can be obtained as well from the sparks of franklinization.

In electrization by contact, the effects are very different, according as the sparks between the exciters of the machine are intermittent or continuous. In the first case the body is traversed by waves upon waves of sinusoidal nature (the fundamental wave accompanied by its harmonics).

The waves of these currents, being directly given their vibratory origin, are perfectly sinusoidal, contrary to those obtained in the induction of transformers, wherein these sinusoidal currents are made to traverse the conductor. The transformation changes completely the form of the curve so that by applying the laws of induction it is easy to keep account of them. Such, especially, is the case for the currents which we produce by this method of induction in our electrode. The effects obtained by currents proceeding from transformers should be distinguished from the effects obtained from sinusoidal currents, for their curve is very complex. The effects produced by large waves formed by the union of little sinusoidal waves are mainly muscular contraction. These currents, because of their form, are well borne and make a valuable part of muscular electrization. In the case where the spark between the exciters of the machine is continuous, the action of the alternating currents are very peculiar and quite different from those hitherto attributed to currents of this kind. The electrodes held with both hands give scarcely any sensation, as has been noted by all the authors who have taken up the question, but if the action of the current is localized; if it is given a great density on a single point, then the effect is different. To localize the action of the current we use a blunt metallic point; this point passed over the surface of the skin

is scarcely felt as long as it does not pass over a nerve, but if it passes over a sensory or moter nerve its functions are excited in all its distribution under the electrode; the sensation in the branches of the sensory nerve is so well marked that it permits the limits of the region innervated by that nerve to be determined with great precision. Yet, moving the electrode less than a mm. is sufficient to cause all sensation to disappear.

These currents therefore are a better means for localizing nervous excitation than has been found hitherto, and this property makes us hope physiologists will use them in determining functional localization of the nervous system—central and peripheral.

The properties which we have shown as possessed by these alternating currents of high tension and great frequency seem to invalidate the law enunciated by d'Arsonval regarding the relationship which exists between the number of alternations and the faculty of exciting nerves; but the currents we here describe are produced by an entirely new means, and the different results can be explained by the differing qualities in the currents; it is possible that the currents produced by electrostatic machines, while partaking of the properties of the Tesla currents, may be formed of large waves composed of small sinusoidal waves as we have indicated above, and that may be true of them even when the sparks between the exciters have the appearance of continuity.

Notes

Electricity in Gynecology.

The American Journal of Obstetrics, Vol. XXVIII, No. 4, 1893, contains a masterly article entitled "Chronic Oöphoritis and its Treatment by Electricity, A Clinical Study" by Edward Sanders, M. D., of New York. After a thorough presentation of the history, etiology, pathology and diagnosis of the disease, the writer considers the treatment under the three divisions, (1) medical, (2) surgical and (3) electrical in a comprehensive and impartial manner. The writer has treated 65 cases in all by means of continuous and induced currents of electricity. Of these only 25 continued the treat-

ment over a period sufficiently long (4 to 6 months) to test its efficacy, and of this number 22, or 88 per cent., were completely cured. We quote the following from the writer's conclusions: "We may fairly conclude that for the cure of chronic oöphoritis there is no remedy now before the profession which is the equal of electricity; the cure being obtained without any risk whatever to the patient, be the case simple or complicated, recent or of old standing, the only contra-indications being the presence of pus, the occurrence of acute peri-uterine inflammation, or the existence of old, unyielding adhesions." The technique of the electric treatment employed by the writer is described in detail in the article.

Misuse of Electricity.

The following from a correspondent is a sample of the inquiries which we receive not infrequently regarding preparation for the practice of electro-therapeutics:

"I would like to know whether there are any courses of study at Ann Arbor designed to fit one for thorough work in medical electricity alone? I am thirty-eight years old, am living with a married brother and am anxious to learn something whereby I can become self-supporting. I have always been very much interested in medicine, and was benefitted so much by electrical treatment several years ago that I am anxious to become proficient in the use of the battery."

The writer entertains the erroneous opinion, far too prevalent in the minds of physicians as well as the laity, that with a little knowledge of a battery any person of average intelligence is competent to practice electro-therapeutics.

Members of the medical profession by permitting and advising the use of electricity by nurses, and even by patients themselves, have sanctioned and encouraged this false idea both to the detriment of electro-therapeutics as a means of cure and to the injury of many sufferers.

As reasonable would it be for the physician to place in the hands of a nurse or patient a solution of sulphate of strychnia of indefinite strength and suggest that it be used occasionally as a tonic as to sanction the use of electricity in a like unguarded manner.

VOLUME I. APRIL, 1894. NUMBER 2.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN

Published Quarterly by Register Publishing Co., Ann Arbor, Mich.
Subscription Price One Dollar a Year.

The Constant Current.

The constant or galvanic current has a wide range of therapeutic applications.

Its use, at one time largely empirical, is now based upon its known physical and physiological action on the constituents of living tissues; and the therapeutic results sought to be attained by means of it are more uniformly successful in proportion as the operator is familiar with and pays heed to the physical and physiological effects it produces and skillfully adapts them to the requirements in the disease treated.

The physical effects which attend the passage of a constant current through living animal tissues, are, as far as known, included under electrolysis, cataphoresis and catalysis, all of which can be turned to account therapeutically.

The physiological effects that have been noticed of such currents are to some extent dependent, no doubt, upon the physical phenomena; but there are others, such as the electrotonic effects induced in a nerve whereby its excitability is heightened or decreased according as it is subjected to the

influence of the current at the anode or the cathode, and the contractile responses of muscular tissue to the *make* and *break* of the current, both in health and disease, that are peculiarly physiological, due directly to the properties possessed by these tissues while in a vital state. The physiological responses in nerve and muscle resulting from the passage of a constant current through them under certain conditions have become to the neurologist an indispensable requisite for determining the functional and structural condition of nerves and muscles when for any reason their integrity is called in question. Electric diagnosis does not depend wholly upon the use of the constant current, but taken in connection with induced current applications it elicits information regarding the action and state of nutrition of nerves and muscles with a certainty and accuracy that contributes much to both the diagnosis and prognosis of disorders affecting these structures.

Aside from these direct uses of constant currents, they, in common with alternating or induced currents, are of indirect service in therapeutics in serving to heat metallic points, blades etc., for cautery purposes, and for lighting exploring lamps for diagnostic purposes, and for aiding in operations where artificial light is required.

We may, therefore, for the present, group the therapeutic uses of the constant current under the following heads:

Electrolytic action.
Cataphoric action.
Catalytic action.
Electrotonic action.
Contractile action.
Thermal action.

Each of these actions of the constant current we will treat in detail in the *Bulletin*, and in connection with the discussion of the peculiar action itself we will give a description of such methods and appliances as are in our judgment most worthy of mention in securing the therapeutic effects that such action is capable of producing.

It must be understood at the outstart that the separation of the effects produced by the passage of a continuous or gal-

vanic current through living tissues into the groups above enumerated, is to a certain degree forced and arbitrary. Probably in no application of the continuous current are the effects strictly confined to any one of the groups of phenomena which we will classify under the various headings mentioned, but all enter more or less into and contribute their share of action to the result obtained. The prominence of certain phenomena in the application made alone justifies the use of one or the other name in any particular instance.

Dynamo Current Controllers.

The day is near at hand when the dynamo will displace the primary battery as a source of electric energy for therapeutic purposes in all places where it is available. There will still be a field of usefulness for primary batteries of a portable type, but the non-portable and cumbersome plants made up of groups of fragile cells containing perishable elements and corroding fluids will be tolerated only so long as the operator is beyond the range of the dynamo's transforming power. Such appliances as adapt the various dynamo currents to physicians' needs are already not a few. Some of the most efficient and best known of these have been sent to this laboratory for examination, and descriptions of them will be published in the *Bulletin* as space permits, with the view of acquainting our readers with their peculiarities and adaptation to therapeutic work. Among those already received we should mention

The McIntosh Current Controller,
The Gish Ideal Rheostat,
The Knapp Rheostat,
The Vetter Current Adapter,
The K. A. P. Rheostat,
The Wotton Surgical Transformer.

The first of these we describe in the present issue of the *Bulletin*.

Positive Electrolysis.

By *positive electrolysis* is meant electrolytic action as brought about at the positive electrode or anode, while *negative electrolysis* refers to the effect produced by means of the negative pole or cathode. Electrolytic action upon living animal tissues in immediate contact with the electrodes admits of no question. The drying, coagulating effects that follow the application of the anode and thes oftening, liquefying influence of the kathode are too well known and too readily demonstrated to be long an occasion for doubt. These immediate polar effects of the constant current have been the means of accomplishing much in electro-therapeutics.

Whenever vascular derangements occur, giving rise to abnormal dilatations such as nævus, circoid or other aneurisms, varicose veins and such like conditions, the coagulating action of the anode can be brought to bear upon the faulty vessels with a precision and freedom from unnecessary damage that commends it as superior to all other procedures. Where hemorrhages and ulcerations are due to relaxed and boggy conditions, as is frequently the case upon the cutaneous surfaces or accessible mucous membranes, the application of the anode promptly corrects the morbid state. Varicose and phagedenic ulcerations; eroded surfaces retarded in healing by excessive granulations; mucous surfaces congested and abnormally vascular or studded with vascular vegetations, as is so often the case in the nasal passages, the pharynx, the urethra, and in the interior of the uterus; in fact all abnormal local conditions where astringent measures are indicated present suitable conditions for the use of the anode of the continuous current.

If these abnormal conditions arise upon an accessible surface, either cutaneous or mucous, a variety of suitable electrodes are constructed by which to make application of this anodal electrolytic property of the current. These should be of metal that is not corroded by the nascent elements set free at the positive pole during the passage of the current, such as oxygen and chlorine. Platinum, gold or car-

bon serve this purpose best. If, however, it is desired that the therapeutic action of certain secondary products that can be generated electrolytically at the anode be utilized, then the composition of the electrode may be of such material as will give rise to these products. Pure copper and pure zinc have thus been employed as electrodes for anodal applications, whereby much of the therapeutic effect resulting is due to the action of the oxides and chlorides of these metals generated at the point of application, and caused to penetrate the adjacent tissues by the action of the current (cataphoresis). Some of these metallic salts are germicidal, and where the deranged state of nutrition makes a suitable culture field for the generation of bacteria, and thus prolongs the pathological process, *metallic electrolysis* proves a therapeutic procedure of superior excellence.

This astringent and germicidal action of the anode of a constant current is of peculiar advantage in dealing with such conditions when located in the urethra as gonorrheal inflammation, in the cervix uteri, and in affections of the nasal and pharyngeal mucous membranes. Various parasitic skin diseases also affecting the sebacous and hair follicles can be treated successfully by means of needles of pure copper, employed in positive electrolysis. There are circumstances, however, where the formation of metallic salts and their deposit in the tissues as a result of positive electrolysis might prove objectionable. Should an operator attempt the removal of superfluous hairs, or other blemish, on an exposed surface of the body by means of a steel, copper or other corrodable metal as the anode, the metallic salt formed would leave an indelible pigmentation at the point of operation. For this reason *negative electrolysis* is usually employed when it is desirable to avoid this effect.

Negative Electrolysis.

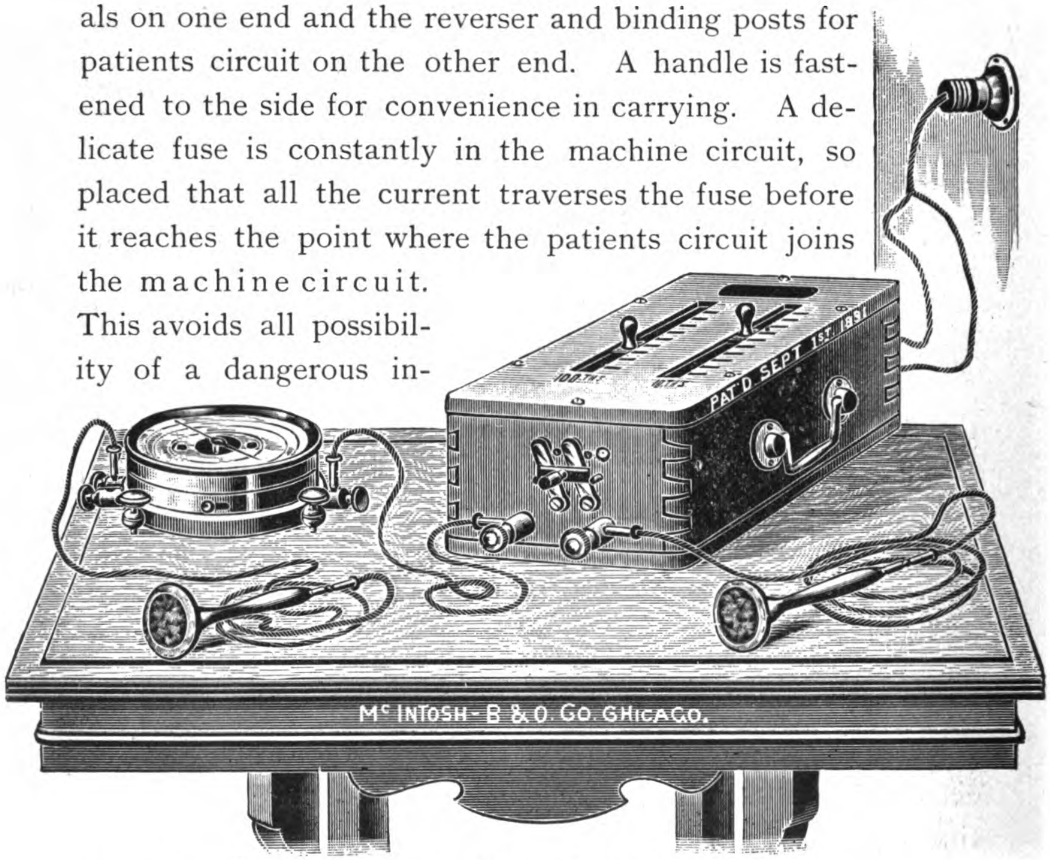
When the negative electrode of a continuous current is brought into contact with living animal tissue, hydrogen and the alkaline elements which enter into the composition of those tissues are set free in immediate contact with the electrode. When thus liberated they may, if in sufficient amount, react injuriously upon the adjoining tissues. Caustic soda and caustic potassa are two forms of alkali most likely to be formed, and these again combine with fats and albumen and form soluble compounds. The quantity of alkali thus gathered at the negative electrode is directly proportional to the strength of the current and to the length of time it is passing. A small current allowed to act on tissues for a long time will have an effect equal to a greater amount of current during a less time. The amount of current and the length of time during which it is permitted to flow through a part must be determined by the effect desired. Gross destruction of tissue can be caused either by positive or negative electrolysis. The eschar resulting from positive electrolysis is dry and hard, while that resulting from negative electrolysis is soft and pliable. The latter is better adapted, therefore, for that class of therapeutic applications where it is not desirable to limit the blood supply or nutritive channels in the part after the effect has been accomplished for which the electrolytic application is made. In removing superfluous hairs, warts, moles, and other non-vascular growths, negative electrolysis is the more suitable procedure, especially since it is not necessary to employ with this pole a non-corrodable electrode, there being no possibility of staining the tissues with metallic salts in using a steel point when the negative pole is employed for this purpose. As many of these operations are made for cosmetic effects, these are points that should not be disregarded.

But the therapeutic effect of negative electrolysis is not limited to those procedures where actual decomposition of tissue takes place, or at least where such destruction is noticable to the naked eye. Cicatricial tissue, arising from a var-

iety of causes and located in various places, oftentimes assumes grave pathological importance. Function may be seriously impeded by it, whether it has resulted from traumatism, burns, scalds, acid erosions or inflammatory action. It has been found that negative electrolysis which stops short of surface destruction of tissue has the power to soften and relax this fibrous, or scar tissue, and thus remove or mitigate the evil effects which its presence has caused. This result may not be justly attributed to electrolytic action alone, for no doubt the process termed *cataphoresis* contributes a share of the influence, and the vital forces residing in the part cannot be left out of the account. But while we are unable to justly proportion to each agency its proper share in the process, it is nevertheless true that negative electrolytic action starts a retrogade metamorphosis, or change, in the dense fibrous network of cicatricial tissue, which causes it to soften and relax. This can be done without bringing about any gross destruction of tissue, or producing eschars. It is a misuse of this method of treatment to employ currents strong enough, or long enough to cause erosions. The relaxing and changed nutritive effects produced on cicatricial tissue under the influence of the negative electrode do not require such strong currents. Wherever, therefore, through inflammatory or other agency, such scar tissue has become a serious impediment to function, as in stricture of canals and passageways such as the œsophagus, urethra, cervical canal of the uterus etc., negative electrolysis will oftentimes prove a valuable means for affording relief by resolving the tissue that occasions the constriction. Abnormal growths closely allied in structure to cicatricial tissue, such as fibroma and uterine myoma, are also amenable to negative electrolysis, and it is through its agency that Apostoli and his followers have achieved their successes in the electric treatment of this class of growths.

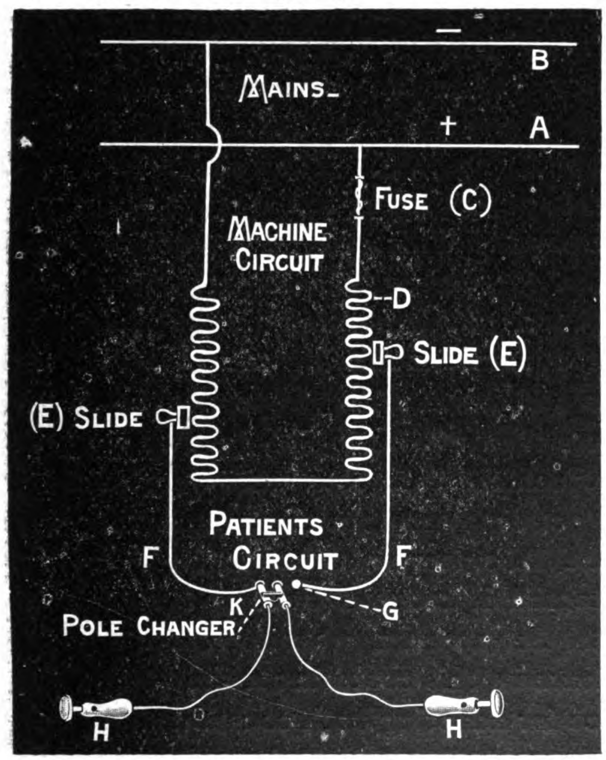
The McIntosh Current Controller.

This controller is designed for portability, though not at the expense of durability. It is contained in a neat hardwood case $6\frac{1}{2}$ in. by 9 in. by 4 in., having the index and regulating handles on the top, the binding posts for the machine terminals on one end and the reverser and binding posts for patients circuit on the other end. A handle is fastened to the side for convenience in carrying. A delicate fuse is constantly in the machine circuit, so placed that all the current traverses the fuse before it reaches the point where the patients circuit joins the machine circuit. This avoids all possibility of a dangerous increase in the current strength in the patients circuit.



The fuse is so adjusted that a current of one-half an ampere in the machine circuit would instantly melt it and thus disconnect the instrument entirely from the dynamo. Under no circumstances can a harmful current pass through the patient. The reverser is in the patients circuit to avoid the sparking and burning of contacts that would result from reversing the heavier current carried by the machine circuit.

The controller works on the well known "shunt" principle. The machine circuit consists of a succession of coils, 19 in all, joined in series and having a united resistance of 209 ohms, about the resistance of an ordinary 100-volt lamp. The patients circuit is so arranged with sliding contacts that the patient may be placed in a shunt to one or more coils. The coils vary in size, but are so proportioned as to modify the current in tenths and hundredths. The sliding contacts are arranged in two rows, each row having its own index. One row is connected with the larger coils, and consequently each coil in this row divides the E. M. F. in the machine circuit by ten. The remaining coils are connected with the other row of contacts, and each coil divides the E. M. F. by one hundred. The two rows may be used singly or together. The contact consists of a heavy brass roller sliding on a flat brass plate and held tightly in contact with the plate by a flat brass spring. The following diagram illustrates



the essential parts of the instrument, and will enable the reader to clearly understand its construction and action. The laboratory test was made with an E. M. F. of 90 volts in the patients circuit when shunt to the entire number of coils. A resistance of 1560 ohms was placed in the patients circuit, in which was included also a Weston milliampere meter. A Weston volt meter was connected shunt to the patients terminals. The follow-

ing table will show the E. M. F. and current in patients circuit, with the sliding contact at various points on the index:

Left Slide.			**Right Slide.**		
INDEX.	E. M. F.	CURRENT.	INDEX.	E. M. F.	CURRENT.
1............	8 Volts.	7 Mil'amps.	1............	1.1 Volts.	.9 Mil'amps.
2............	19 "	15 "	2............	2.3 "	2. "
3............	29.2 "	25 "	3............	3.51 "	3 "
4............	40 "	32 "	4............	4.24 "	3.61 "
5............	50 "	40 "	5............	5.35 "	4.5 "
6............	59.2 "	49 "	6............	6.93 "	5.84 "
7............	69.3 "	58 "	7............	8.21 "	6.9 "
8............	80.1 "	67 "	8............	9.2 "	7.8 "
9............	90 "	75 "	9............	10.63 "	8 93 "
			10..........	11.89 "	10. "

It will be seen from these tables that the voltage and current increase and diminish in corresponding ratio, and this of course holds true no matter what the source of E. M. F., whether from a constant current dynamo, an alternating current dynamo, or a series of primary batteries. The laboratory contains a number of plants of various forms of primary batteries, each made up of fifty cells. The voltage furnished by these varies from 60 to 78, according to the make of battery of which they are composed. This current controller seems to work quite as well on the current furnished from any one of these batteries as upon that generated by the Edison or other constant current dynamo, modifying the E. M. F. and the current by tenths and hundredths proportionate to the initial voltage, whatever that may be. The dynamo generating the current upon which the foregoing tests were made is used for distributing power to motors throughout the city. The current enters the laboratory with an E. M. F. of five hundred, but this potential is reduced by lamp resistance to the desired amount. It appears, therefore, from these observations that we have in this controller a simple and efficient mechanical device for adapting both constant and alternating currents, or currents derived from primary batteries, to the physicians use.

The National School of Electricity.

We are in receipt of communications from physicians and others almost daily asking for advice and direction as to how they may prepare themselves in a proper manner for the practice of electro-therapeutics; what text books we would advise; what course of study they should undertake. In attempting reply to these inquiries, we have been confronted by the fact that such preparation cannot be derived from text books. Touch and sight must be directly engaged, and personal experience gained with the appliances through which the principles and phenomena of electricity are made familiar to the mind. The teacher skilled in his calling must be at hand to whom the inquiring mind can appeal, and by whom the innumerable perplexities that assail the understanding of the novice may be cleared up. The plan of organization of the "National School of Electricity," recently announced, bids fair to provide just such facilities as we are needing in this direction, and in such a manner that the widest benefit will be secured. Its aim is to establish a practical system of instruction in modern electricity after the Chatauqua plan of local class organizations directed from one centre. The conception originated with the T. P. Barrett, Chief of the Department of Electricity at the World's Fair. The following extracts from the "Prospectus" of the School will acquaint our readers with the scope of the work it proposes to undertake.

"During the progress of the World's Fair, the Chief of the Department of Electricity received hundreds of letters from all parts of the country suggesting, in many cases urging, a course of lectures on practical electricity in connection with the department. As the great Exposition neared its zenith the letters and appeals became more urgent in tone, and the Chief of the Department enlisted in the cause many of the experts in charge of exhibits. A small auditorium in the electrical building was devoted to the undertaking and the lectures were begun. By the time the third one was delivered the attendance became so great that the seating accommoda-

tion was entirely inadequate, and the dissatisfaction on the part of those unable to secure admittance became so outspoken that the lectures had to be discontinued, no larger hall being available. The subject was not allowed to die, however, and the Chief was besieged more strenuously than ever, and after the Fair was over the appeals took the form of a demand for a permanent substitute.

"In obedience to this demand, the Chief of the Electrical Department has secured the co-operation of the ablest men in the electrical profession, and in so far as may be, the original undertaking will be carried out in a permanent and necessarily modified form.

"It is the intention to organize a class in electricity in every city and town where the population will justify it; to provide a thorough instruction under a system that will make the study of electricity not only interesting but of great commercial value to students.

"Weekly meetings of each class will be held permanently at some centrally located point, agreeable to the students. At each meeting after the first, there will be a short review with questions and answers. The "lesson leaf," which will be referred to later, will contain the basis of this review.

"The course is intended to cover a period of 40 weeks, with one new lesson for each week. The course will occupy about one year, allowing for holiday seasons and intemperate weather. It must not be understood that students can be taught all there is to learn of electricity in this brief time, but there is no doubt that at the end of the course students will have a clear grasp of the subject, and will be familiar with every kind of electrical apparatus, and fully competent to complete their education along scientific lines at their leisure.

"The lessons will be short, and in language that students of most limited education can readily understand.

"For each week of the course a "lesson leaf" will be issued, one at a time, that will contain all information necessary to a complete understanding of the subject. After the first lesson, the leaf will also contain questions upon the lesson

of the previous week, calculated to fix the main points in the students mind. The lessons will be accompanied by drawings sufficiently explanatory, and classes will be furnished with the simpler form of apparatus for experimental work, and for class demonstration. Blackboard work by the instructor will also enter largely into the system of teaching.

"Only those things will be taught that are backed up by the highest scientific authority, but it will be the endeavor not to confuse students by citing vast arrays of testimony in support of theory and practice.

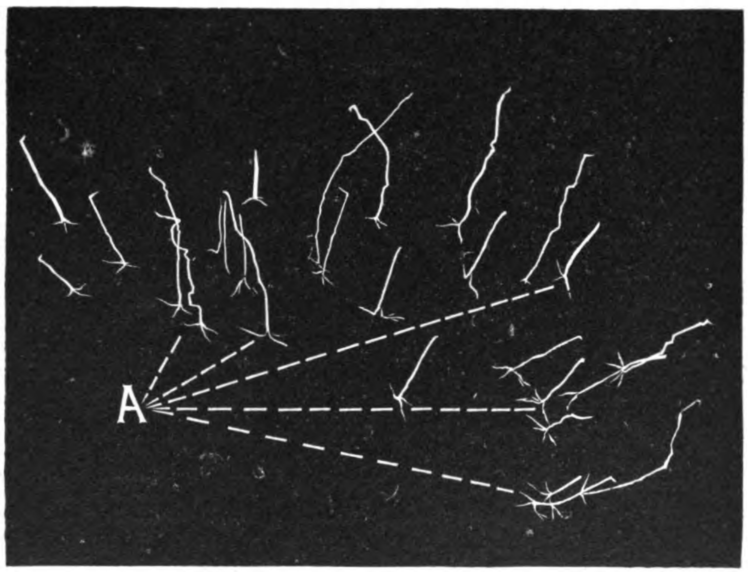
CURRICULUM.

The curriculum will embrace the foundation principles upon which the science of electricity is built, definitions of terms and phrases, and the construction and operation of all kinds of electrical apparatus. The lessons, prepared under the direction of the Faculty, will embody a principle of teaching specially adapted for the work contemplated, because of its simplicity. After thoroughly but briefly covering the first principles of the science, the lessons will proceed at once along practical lines to the construction and operation of the various classes of apparatus. We are pleased to see that electro-therapeutics has not been overlooked in the preparation of this curriculum. It seems to us entirely feasible to adapt the teaching in these local schools to the requirements of those physicians who desire to fit themselves for using electricity in some form as a therapeutic agent, but who are not able to abandon their practice and leave home for sufficient time to obtain the necessary information.

Notes.

We regret to learn of the serious illness of Plym. S. Hayes, M. D , Professor of Electro-Therapeutics in the Post Graduate School, Chicago. Dr. Hayes has been one of the most enthusiastic workers in this field of therapeutics, and has made many valuable contributions to its literature which have

found ready entrance into home and foreign journals. Five months ago, at the time he was first taken ill, he was engaged in some researches by which he sought to demonstrate the unity in therapeutical action of all forms of electrical energy, the apparent differences being those of degree only and not of kind. In experimenting with the static charge in the treatment of a carcinoma of the breast he made some photographs of the sparks as they passed from the electrode to the skin. He was especially interested in noticing that at the instant the spark approached the cutaneous surface it divided, taking a number of paths which he concluded to be lines of least resistance, presumably the mouths of sebaceous follicles and sweat glands. This division of the spark, resembling a crow's



foot, is well illustrated in the accompanying figure which is a reproduction of some of these photographs. It is our earnest hope that Prof. Hayes may be spared for many more years of efficient service.

Dr. W. J. Morton, Professor of Nervous Diseases and Electro-Therapeutics in the New York Polyclinic, is still engaged in investigations with a view of determining the polarity of diseased foci. Some of his experiments, which we had the privilege of witnessing during a recent visit to New

York, served to demonstrate that focalized lesions of the spinal cord of the nature of chronic inflammation exhibit a polarity quite different from that of normal tissue. It is hoped that researches of this nature will reveal facts that will be the foundation for a system of electro-therapeutics constructed on principles more exact and uniform in action than those evolved from the present empirical methods.

The International System of Electro-Therapeutics, edited by Horatio R. Bigelow, M. D., and recently issued by the publishers, F. A. Davis & Co., of Philadelphia, is a very creditable work and will do much to enlarge the interest in this branch of therapeutics. It furnishes a storehouse of exact information derived from sources calculated to insure confidence on the part of the reader. We understand it is having a large sale, and it certainly deserves it.

VOLUME I. JULY, 1894. NUMBER 3.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN

Published Quarterly by Register Publishing Co., Ann Arbor, Mich.
Subscription Price One Dollar a Year.

Cataphoresis.

The physical phenomena grouped under the head of cataphoresis or electric-endosmose should be considered next to those of electrolysis in any attempt at a rational explanation of the changes affected in a normal, or diseased state of the body by the transmission of a constant current through it.

We will not attempt here to go into the history of experimentation, or the citation of authorities. The facts of electric-endosmose have become an authentic chapter in the science of electric phenomena and have received contributions from many of the ablest physicists, from the time when Reuss of Moscow in 1807 first drew attention to the subject, down to the present day.

The first study of these phenomena in the physiological field is credited to Porret. His researches were published in the Annals of Philosophy in 1815.

The physical facts as they stand related to the therapeutic employment of them are briefly these: Ordinary osmosis is

the transfusion of liquids of different densities and composition through porous septa or membranes. When two such liquids differing in densities are at the same level, but separated by such a porous partition, an interchange takes place but the lighter liquid flows toward the denser more rapidly and brings about a difference in level in favor of the denser liquid. The current that is directed toward the higher level is called the endosmotic current. The forcing of liquids through capillary spaces is attended by the development of electro-motive forces and according to Graham a chemical action on the material of the septum invariably accompanies osmotic action. These osmotic processes, therefore, which are constantly going on in all parts of the normal living body, cause differences of electric potential on the surface of their partition walls and electrolytic action is in all probability the result.

These conditions are peculiarly modified by a constant current introduced from without. The natural endosmotic current may be quickened in its flow by the aid of an electric current flowing in the same direction, that is, from positive to negative; or natural osmosis may be retarded or checked by an opposing electric current. These phenomena, due to the influence of a constant electric current in modifying the ordinary processes of osmosis, are what is meant by electric-endosmose, or, when applied to animal tissues, cataphoresis.

The numerous experiments of De la Rive established the following generalizations regarding electric-endosmose:

"The force with which a galvanic current transports a liquid through a porous partition from the positive to the negative wall is measured by a pressure which is directly proportional to the intensity of the current, to the electric resistance of the liquid, to the thickness of the porous partition and inversely proportional to the surface of that partition."

These conclusions serve as guides to our therapeutic methods when we come to make use of these physical processes in the treatment of diseased conditions, for by heeding them we form a more correct estimate of the strength of current, and the size and nature of electrodes required for special applications.

Morbid states within the body may be modified by cataphoresis either directly or indirectly. The power we have, through the use of the galvanic current, to drive fluids and substances dissolved and held in suspension in them, away from the positive electrode and transport them to the vicinity of the negative electrode is one which, when it becomes more fully apprehended by the medical profession, is destined to play an important rôle in therapeutics. By means of it morbid accumulations of fluid in serous and synovial sacs may be driven out, rheumatic and gouty deposits may be redissolved and removed, congestions may be made or allayed and conditions may be established at the will of the skillful operator that will effect decided changes for the better in the local or general nutritive processes. This may be properly termed the direct use of the cataphoric action of the current and is what Prof. Houston has chosen to designate *normal cataphoresis*, while that for which he suggests the name of *abnormal cataphoresis* is what we refer to as the indirect therapeutic application of the principles of electric-endosmore. By indirect cataphoresis we mean the employment of it for the purpose of conveying medicines in solution into the body through the integument or mucous membranes by bringing them in some manner into the channel of the electric current at the positive pole and so causing them to penetrate these membranes.

This can be made to serve the purpose of both general and local medication; general, when for any reason it is deemed best to make the skin the avenue of ingress for such medicines rather than the alimentary canal. Many remedies can be carried into the system in effective quantities through the pores of the skin by cataphoresis that, without its aid, would find in the various layers of the integument an impassable barrier. Thus by making the body, immersed in a medicated bath, the negative terminal of a suitable constant current, the medicated solution surrounding the body being rendered positive would insure a certain per cent. of the medicine gaining entrance to the subcutaneous tissues. We do not know to what extent so-called "electric baths" have been given in this manner and

with this purpose at our sanitariums and hydropathic establishments, but it is capable of being made an efficient method of systemic medication for all electro-positive substances that possess curative properties such as many of the soluble alkaloids or soluble combinations of these. The constituents of our natural mineral waters, of which we have such a variety in this country, might be studied with the view of increasing their medicinal action by this method of introduction. The direct action that could be brought to bear upon the deeper layers of the skin by this means naturally suggests itself to our minds and in affections such as those in which sulphur and arsenic are so largely employed as remedies, the deeper layers of the skin, where the pathological process is seated, could be effectually treated by this method should a soluble salt of one or other of these remedies be dissolved in the bath.

For the local medication of an organ, joint, nerve or gland it is only necessary that a suitable electrode be devised in order to secure the effect desired with a remedy that can be used in this way.

Cocaine anæsthesia, which cannot be brought about by topical application of the drug to the skin, is quite effectual when induced cataphorically. And the local effects of veratria, aconitia, menthol and a variety of other remedies used to dull the sensibility at nerve terminals are greatly intensified if applied by this method.

It has been suggested by Dr. W. J. Morton that cataphoric action might be employed with advantage for *demedication* of the system as well. When by any means the tissues have been the receptacles, either by accident or design, of deleterious agents such as lead, arsenic or phosphorus a reversal of the electric current might, in a suitably arranged bath, aid in their removal.

Current Density.

When treating of positive and negative electrolysis in a former number of the *Bulletin*, we indicated the therapeutic effects that could be obtained on tissues by concentrating the current by suitable electrodes either at the anode or cathode.

The object of the increased density of current at the point of application in these cases is to disintegrate the tissue in immediate contact with the electrode. Such destruction of tissue will take place whenever and wherever the electric energy is in quantity and intensity sufficient to disrupt the chemical combinations of which the tissues are made up. But while this destruction and decomposition of tissue is the result sought in some therapeutic applications, it is very undesirable in others. When the application is made with the view to secure therapeutic effects deep within the body, and influence the nutrition or effect a change in the composition of the fluids or tissues of an organ remote from the skin which overlies it, precautions must be taken to prevent the current from doing damage along its pathway as it is conveyed to the disordered region.

The greatest obstacle to the introduction of a constant current to structures beneath the skin is the skin itself. In its dry state the skin offers enormous resistance to the passage of the current, and the electric energy which is applied to it is largely expended upon its surface unless measures are taken to reduce this resistance. The skin's resistance can be greatly reduced by keeping it thoroughly moistened with saline solution, and the destructive effects of a concentration of electric energy upon it can be avoided by using broad electrodes at the points of application. A lack of knowledge of these conditions, or a disregard of them, has been the cause of much bad work in electro-therapy. The operator, in using a constant current, is inexcusable for producing an accidental eschar.

At the point of contact of the electrode with the integument, the section of the circuit is determined by the

active surface of the electrode. Consequently the density of the current at this point varies with the active surface of the electrode employed, and in an inverse ratio. In order that the electrode may be uniformly active over its entire surface in contact with the skin, it should be evenly and thoroughly covered with some material capable of receiving and retaining moisture. Should a portion of the electrode during the treatment be allowed to come in immediate contact with the integument, owing to the better conductivity up to this point, the density of current would be increased upon this spot of integument and electrolysis of the skin might result. Or again, should the material used for covering the metal or carbon electrode be moistened imperfectly, the density of current would be greater at these spots on the skin in contact with the well moistened parts of the covering, and thus density might be sufficient to cause disintegration of the skin.

We possess no absolute values of density to serve as a point of departure in these applications of constant currents to the deeper structures of the body. There is great variation of resistance offered by the epidermis in different patients, and in different parts of the body in the same patient. A current bordering on a destructive degree of density usually gives rise to pain, oftentimes to severe pain, before much electrolytic action has taken place; and yet this is not a safe guide to the operator even if he should choose to subject his patient to the test, for there is the greatest variability in patients in their sensitiveness to pain. Moreover, the disease to be treated may be one associated with cutaneous anæsthesia where the pain signal is wanting.

In addition to this, another difficulty presents itself in any attempt to establish a unit of density for electro-therapeutic work. A density which suits a current of certain strength, and with an electrode of given surface, is much too great for a stronger current and a larger electrode. Thus, if an electrode having 1 sq. cm. of surface can remain applied during ten minutes with a current of 1 ma., it is not to be inferred that another electrode twenty times greater could

remain applied during the same time with the same density, that is to say, with a current of 20 ma. To employ this strength of 20 ma. without causing pain and without danger of scars, it would be necessary that the smaller electrode should have a surface of about 115 sq. cm. With an electrode of only 20 sq. cm., the strength of the current should not exceed 7 ma. for an application of ten minutes; and the density is then 0.35 of a ma. per sq. cm. This shows that in medical practice the value of the electric density cannot be absolute, and that this value should diminish as the strength of the current augments.

Boudet de Paris sought to establish experimentally the value which may be given to the density with electrodes of different surfaces, and for currents of a strength varyfng from 1 to 25 ma. The results of these researches are embodied in the following table:

Electrode Surface in sq. cm.			Current in Milliamsperes.	Electrode Surface in sq. cm.			Current in Milliamsperes.
1	will safely	carry	1.	24	will safely	carry	7.75
2	"	"	1.50	25	"	"	8.
3	"	"	2.	26	"	"	10.
4	"	"	2.25	50	"	"	15.
5	"	"	3.	75	"	"	18.
6	"	"	3.50	100	"	"	20.
7	"	"	4.	125	"	"	21.
8	"	"	4.25	150	"	"	22.
9	"	"	4.50	175	"	"	22.5
10	"	"	4.75	200	"	"	23.
11	"	"	5.	225	"	"	23.3
12	"	"	5 25	250	"	"	23.6
13	"	"	5.50	275	"	"	24.
14	"	"	5.75	300	"	"	24.3
15	"	"	6.	325	"	"	24.5
16	"	"	6.25	350	"	"	24.6
17	"	"	6.50	375	"	"	24.7
18	"	"	6.75	400	"	"	24.8
19	"	"	6.90	425	"	"	24.9
20	"	"	7.	450	"	"	25.
21	"	"	7.15	475	"	"	25.
22	"	"	7.25	500	"	"	25.
23	"	"	7.50				

The values given should be regarded as ~~means~~ averages, but as his researches extended over a large number of patients, and consequently on integuments differing in resistance. there is reason to consider the estimates as fairly precise, and, as far as we know, this is the only attempt that has been made by any electro-therapeutist to determine the limit of density of a constant current that can be passed through the integument without doing injury to it.

The Constant Current as a Bactericide.

Researches have been in progress in this laboratory for a number of months with the view of determining the rôle of the constant current in restraining the action of pathogenic bacteria. No positive conclusions have yet been reached. The constant current can be caused to traverse the focus of a pathological process due to bacterial action, no matter in what part of the body such action is going on. It can be readily seen if we discover that such a current, of a strength insufficient to do damage to tissue cells, is yet destructive to germ life, we will have in it the ideal germicide. In anticipation of the results of our own investigations, it may interest our readers to give the conclusions reached by Apostoli and Laguierre, who have for some years been engaged in similar researches.

"The antiseptic and germicidal action of the constant galvanic current, foreseen by one of us since 1885, has been the object of our common researches for the last two years. In a sealed note, deposited in the Academy of Sciences the 12th of of August, 1889, we recorded the first results of our experiments made by placing first the poles at the two extremities of the same guage containing bouillon cultures at a little distance from each other. All our experiments have been controlled by cultures and by the inoculation of an animal. Our first and principle conclusions are:

1st. The action of the constant galvanic current on cultures is in direct ratio with the intensity of the current, valued in ma.

2nd. With the same intensity, all other things being equal, the length of the application is of little account, the intensity of the current remaining always the principal factor.

3rd. A current of 300 ma., and one applied for five minutes constantly, destroyed the anthrax bacilli. The new culture made from the culture thus treated remained sterile, and inoculation of the pig was without effect.

4th. A current of 250 ma., applied five minutes, did not so surely and constantly destroy the virulence. Some pigs still died, but more slowly than the ones inoculated for comparison with the same culture which had not been submitted to the action of the current.

5th. A current of 100 ma. and over, even after an application of thirty minutes, does not destroy the virulence—it produces an attenuation which increases with the intensity of the current, and which makes itself apparent by this fact. The pigs inoculated die in one to two days later than the ones inoculated as a control.

Since the above conclusions were formed, we have established that these effects are independent of the influence of the heat which accompanies all electrolysis, and we have studied the isolated influence of the poles and the inter-polar action of the circuit.

We are able to formulate the following complementary conclusions:

1st. It is possible to suppress the calorific effects of the current, and to obtain as before the destruction and attenuation of the virulence of the germ.

2nd. The positive pole alone destroys or attenuates the vitality of the pathogenic organisms which are indifferent to an inter-polar action and the action of the negative pole.

3rd. The antiseptic action of the positive pole (in the midst of a distinct culture, entirely separated from the negative pole) shows itself with a more feeble current than in the first experiment, where, the two poles being contiguous, their reciprocal action impaired it. Thus the positive pole does not destroy with 50 ma. during an application from five to thirty

minutes; but beyond, the attenuation begins and increases progressively to become constant in the first five minutes between 100 and 150 ma.

4th. The general conclusion which is deduced from our researches is that the continuous current in medical dose (50 to 300 ma.) has no action *sui generis* on the microbic cultures in a homogeneous medium, and that this is due only to positive polar action, resulting from the freeing of the acids and oxygen.

The justification of the intra-uterine application finds experimentally its most powerful argument.

The germicidal action that we have already studied on the anthrax bacilli and the germs of pus exerts itself only in the neighborhood of one pole, the positive, and there is no intra-polar germicidal action. This then is the law that we have discovered for many germs, after carefully observing them, and we are convinced that this law will soon become general. Applied in an actual case, this law says to you—Do you wish to work as actively as possible against the uterine microbes? Use the positive polar action, which ought necessarily to be intra-uterine or parenchymatous to have its full effect, for the pathogenic microbes, if there, are found either in the uterine cavity or in the very roof of the organ. If, as I have said, the microbic origin of the vibroma is questioned, that on the other hand of endometritis and of certain salpingites is beyond all question. By operating in the uterine cavity, you then put yourself in the best physical and clinical conditions for producing the greatest antiseptic action.

In vaginal applications, on the contrary, according as the metallic pole is in direct contact, nothing intervening, with the cervex, or when it is protected by an indifferent substance (chamois or sponge), you employ or you do not employ the caustic polar effect which would be exerted either on the neck (with the bare metallic electrode) or at a distance with the covered electrode. But in either one of these hypotheses (the caustic action at a distance from the neck or the immediate caustic action), the intra-uterine germicidal or antiseptic

action does not exist, since the uterine cavity or the parenchyma are not in immediate contact with nor directly penetrated by the pole, and are merely included in the inter-polar circuit which we have shown to be indifferent to microbes. Thus every vaginal application fatally deprives itself of a very important therapeutic co-efficient which is destined to play a preponderating role in gynæcology."—*Revue Internationale d'Electrotherapie*.

The Constant Current in the Treatment of Endometritis.

The continuous current may be made to play an important role in the treatment of endometritis. Looking into the etiology of this disease, we find we have an inflammatory condition due to the action of micro-organisms in an organ whose power of resistance has been lowered. In consequence we have pain, a leucorrheal discharge, and menstrual disturbances. Applying the action of the galvanic current, especially the anodal action, to this etiology and to these symptoms, we find the one answers to the other point for point. In the first place, we have here an antiseptic and germicidal application for a disease of ascertained microbic origin, co-existing with an agent which may stimulate the circulation of the part and thereby relieve stasis in the inflamed organ. Arterial blood is thus brought to improve the nutrition and restore the normal resistance of the part. This current is sedative, relieving pain both uterine and ovarian; it constructs and tones up the glands, thus lessening the leucorrhœa.

The method of application is simple. The negative electrode should be a broad one, of metal (zinc, wire gauze or perforated brass), well covered with amadou, sponge, lint or clay, and thoroughly moistened in a warm salt solution. The positive may be any medium-sized intra-uterine electrode. It is better to be slightly curved, cylindrical and of copper, zinc or platinum, according to the effect desired.

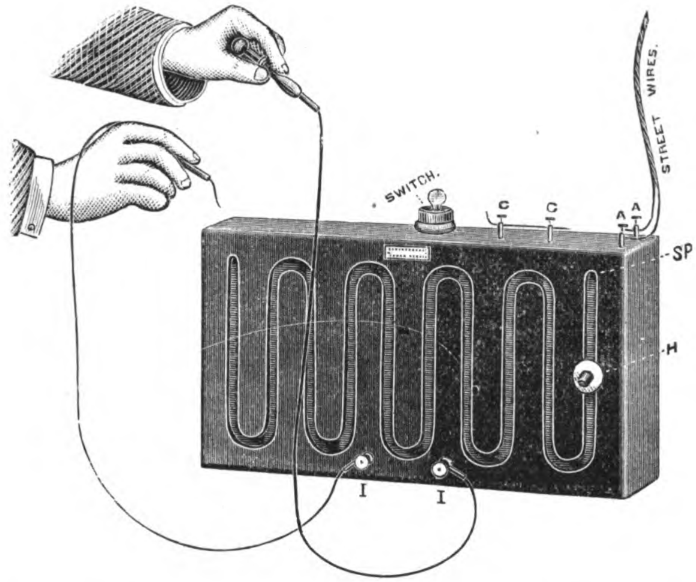
With the patient on the table and the speculum in place,

remove the secretion from the cervical canal, introduce the positive electrode into the cervical canal and put the negative electrode under the patient's hand or upon the abdomen. When all is ready turn on the current carefully and gradually, so as to avoid all shock. When the desired strength of current is obtained, rotate the electrode gently to avoid electrolytic erosions, and let the current pass from five to six minutes. The strength desired in these inflammatory conditions varies from 10 or 15 ma. to 30 or 40 ma. With a new patient it is always necessary to begin with a weak current, so as to allay any nervousness or apprehension. Remove the current gradually, and afterwards carefully cleanse the canal again, making application of such medicinal agents as are indicated.

The treatment should be repeated three times a week, and, if there is dysmenorrhœa, before each period it is well to employ the negative electrode in the uterus.

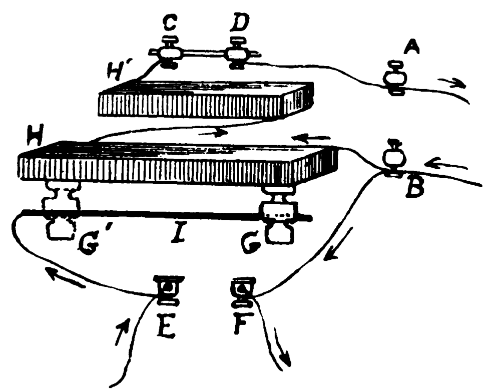
J. C. S.

The Gish Ideal Rheostat.



The instrument here represented is another apparatus designed to adapt the commercial dynamo currents to the physician's and dentist's needs. It is constructed on the shunt plan and consists of a main circuit and a shunt circuit, the latter of which is the patient's circuit.

The main circuit within the instrument is made up of a continuous german silver wire, No. 22, wound on a succession of rectangular wooden blocks covered with asbestos paper. Ten of these wire-wound blocks are exposed through a sinuous slit in the face of the instrument, and in this slit the slide moves which serves to vary the amount of current in the shunt circuit of which it forms a part. The remaining blocks, smaller in size, stand in the rear and are not touched by the slide. We here present a diagram of the working plan of the instrument.



AB are binding posts connecting the instrument with the dynamo circuit.

EF are binding posts for connecting the patient with the shunt circuit.

H represents the portion of the german silver wire resistance that can be made a part of the shunt circuit.

H' that part of the resistance wire that cannot be included in the shunt circuit.

It will be seen from this illustration that while the instrument is in action the dynamo current constantly flows through the circuit BH, H', C, D, A, and that while the shunt circuit remains open at EF; that is, when no patient is in circuit, or when the slide is at the extremity of the slot nearest to B, no current flows through the shunt circuit. But should the slide be moved toward H with a patient in circuit between E and F, then we will have between the points A and B what is termed a divided circuit, and the electro-motive force with which the current traverses the shunt or patient's circuit will be determined by the difference in potential existing between the points B and A, and the distance to which the slide G is moved away from the post B.

This instrument was designed to be used on the Edison 110 v. dynamo circuit, but it can also be used on the alternating system. The resistance of the circuit from B to A is 185 ohms, and from B to the extremity of the resistance H

141 ohms. The difference of potential therefore that can be admitted into the shunt or patient's circuit would be $\frac{141}{186}$ths .of the potential difference between B and A. In case that difference is 110 volts, as in the Edison incandescent circuit, the proportion that would be admitted to the patient's circuit when given its fullest capacity would be 84 volts. This electro-motive force applied to a body resistance of 3,000 ohms, which is a fair average when the integument forms a part of the circuit in contact with both electrodes, would give a current

$$C = \frac{84}{3000 + 141} = 26 \text{ ma} +$$

Which represents the full capacity of this instrument on the Edison circuit, with the amount of resistance named. The majority of treatments with the constant current, when the skin intervenes at both electrodes, does not require a current to exceed 20 ma.

When a mucous surface forms a point of contact for one electrode, the body resistance is very greatly lessened, seldom exceeding 250 ma. Should this instrument be employed on the same voltage with this resistance, we would have

$$C = \frac{84}{250 + 141} = 215 \text{ ma}$$

As its full capacity, a current sufficiently powerful to meet the exigencies of the present treatment of uterine fibroids, endometritis, etc.

The instrument is provided with a switch for letting on the current when it is needed and shutting it off when not in use. Also, a gate CD, is left between two binding posts on the top of the instrument, opening into the main circuit, which can be used at any time for increasing the resistance of the main circuit. The instrument is not designed for nor will it heat a cautery. Neither is it suitable for lighting exploring lamps. The same company have other forms of apparatus especially adapted for these purposes.

Notes.

The "Hayes Memorial Room."

The South Side Dispensary, connected with the Chicago Medical College, has accepted from Mrs. Plym. S. Hayes the gift of electro-therapeutic instruments and library that belonged to her late husband. These were tools which, in the hands and directed by the thoughtful mind of Dr. Hayes, did good service to the afflicted. The trustees should bear in mind, in accepting these gifts and devoting a room to the memory of him whose once they were, that it is not by maintaining a museum of curiosities they will honor him, but only by providing a successor to him in that workshop who is capable of continuing the good work his skillful hands have laid down.

American Electro-Therapeutic Association.

The fourth annual meeting of the American Electro-Therapeutic Association will be held in New York September 25th, 26th and 27th, at the New York Academy of Medicine.

Members of the medical profession are cordially invited to attend. WILLLIAM J. HERDMAN, M. D., President.

MARGARET A. CLEAVES, M. D., Secretary.

Professorship of Electro-Therapeutics.

Mr. A. E. Kennelly, formerly chief electrician of the Edison laboratory but now engaged in electrical expert work in association with Prof. E. J. Houston, of Philadelphia, has recently been appointed professor of electro-therapeutics in the Medico-Chirurgical College of Philadelphia.

National School of Electricity.

We are credibly informed that there are already twenty-seven schools in operation under the management of the National School of Electricity, the plan of which was set forth in the last issue of the *Bulletin*. Aside from those organized in Chicago and its immediate vicinity, St. Louis, St. Paul, Minneapolis, Toledo and other important cities have eagerly adopted this plan for disseminating exact knowledge concerning the science of electric energy.

VOLUME I. OCTOBER, 1894. NUMBER 4.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN

Published Quarterly by Register Publishing Co., Ann Arbor, Mich.
Subscription Price One Dollar a Year.

Physiological Action of Constant Currents.

There are certain reactions which constant or galvanic currents bring about when applied to living animal tissues which cannot be regarded as physical or mechanical effects of the current since they are dependent upon the peculiar properties of living animal tissues and the nature of their response as such to this form of stimulus or excitant. These it seems proper to designate as *physiological effects*, and as they have long served as a rational basis for therapeutic applications with this form of current, a special mention of them is required. The physiological effects that are best known to us both from experiments in the physiological laboratory and from electro-therapeutic observations may be classified as:

Reactions of muscular tissue;
Reactions of nerve tissue;
Reactions of protoplasm.

Muscular Tissue Reactions.—Muscular tissue, whether of the striped or unstriped variety, may be caused to contract by

the direct application to it of either pole of a continuous or galvanic current, the other pole being placed at some distant point upon the body to complete the circuit. The strength of the response in normal muscle will depend upon the strength of the current used. On voluntary muscle in normal condition a certain order of contractions has been found to occur, which order is changed in diseased or degenerated muscle, and this serves, as well as other features in the nature of the response, to distinguish normal from abnormal states in muscular tissue and is a valuable means of diagnosis, a subject which will receive separate consideration in a later number of this BULLETIN. A continuous current, unvarying in its intensity, when applied to a muscle causes a contraction only at the moment when the current is closed or opened; at the "make" and "break" of the current as it is termed. This is due to the fact that irritable tissue requires a change of conditions for excitation. It is seldom true, however, that an absolute uniformity of potential and current can be or is maintained, even for a short interval, in a mass of muscle in the human body through which a current is made to pass—since in addition to the muscle, the skin, tendons, bones, blood-vessels, fluids and nerves form a part of the path for the circuit and in them, and in the muscle as well, the resistance offered to the current is constantly varying so that the current to the muscle is seldom for an instant constant, and while the most marked contractions may be noticed at the "make" and "break", yet the current in the interval between the closing and opening of the current still produces some contractile effects oftentimes quite noticeable.

Involuntary or unstriped muscular tissue responds more slowly to any form of stimulus than the striped variety, and consequently a slowly interrupted galvanic current is better calculated than any other artificial agent to excite contraction in this variety of muscular tissue and does so with the least possible harm. Now when we consider how universal is muscular tissue of one or the other variety in all parts of an animal organism, and how largely the functions of the body are

dependent upon its action, the therapeutic value of an agent that can excite this tissue, when for any reason its action is feeble or faulty, becomes manifest. Involuntary muscle in the digestive tract can be thus influenced, when this effect is required, as in atony of the stomach or torpid peristaltic action in the large or small intestines, resulting in constipation. Local weakness of circulation, giving rise to passive congestion of liver, spleen, lungs, uterus or central nervous system, can be relieved by stimulating the muscular structure in the arterial tunics. The gall bladder and urinary bladder can be evacuated by like means when over distended by reason of feebleness of contracting power, while voluntary muscle in any part when feeble, atonic, paretic or paralyzed from faulty innervation, can be brought into action and its nutrition quickened. Therefore, therapeutic applications of the constant current can be made to muscular structure with the view of exciting its function and improving and maintaining its nutrition when it has suffered impairment by reason of abnormal conditions originating in the muscle itself, or secondary to disorder in its governing nerves.

Nerve Tissue Reactions.—The result following the application of the constant current to nerve tissue differs according to the nature of the tissue influenced, i. e., whether it is peripheral nerve, sensory, motor, secretory or nerve cells in brain, cord, or ganglia. Polar applications along the course of a motor nerve will cause effects on the muscles supplied by that nerve similar to those obtained by direct application to the muscle itself, except that the former method is better calculated to cause the muscle to contract uniformly and in its entirety. This fact is utilized for electric diagnosis in determining the state of the nerve and muscles supplied by it, as well as for treatment when the muscle group supplied by any nerve is impaired through or by reason of fault in its nerve supply.

Sensory nerves react to constant current applications by an increase or decrease of their excitability, according as the application is made with the positive or negative electrode.

The anodal application diminishes the excitability of the sensory nerve, and the cathodal application increases it. Physiologists have made use of the name *anelectrotonus* for the anodal effect of the current, and *catelectrotonus* for the cathodal effect, and electro-therapeutists have adopted these terms.

Wherever sensory nerve action is abnormally increased, causing pain, neuralgia, hyperæsthesia, the anode of a continuous current applied over it for a few minutes will produce in the immediate vicinity of the electrode a sedative effect, provided the current has been used strong enough and remained long enough, and has not been removed suddenly but gradually, that is, the strength of current carefully decreased to zero before the electrode is taken away. On the contrary, if the sensory nerve action is dull, sluggish, the area supplied by it numb or anæsthetic, the application of the cathode will arouse and stimulate it and increase its irritability, and this effect remains for some time provided the same precaution is taken to withdraw the current gradually. It is possible that these electrotonic effects, both upon motor and sensory nerves, are due in a great measure to the electrolytic and cataphoric influence of the continuous current that has been previously considered in the pages of this BULLETIN, but such results are possible only by reason of the peculiar properties of nerve and muscle, and the fact that they respond in a somewhat similar manner to certain methods of application of induction and alternating currents as well as to mechanical vibrations, shows that electrolytic and cataphoric action are not the only causes.

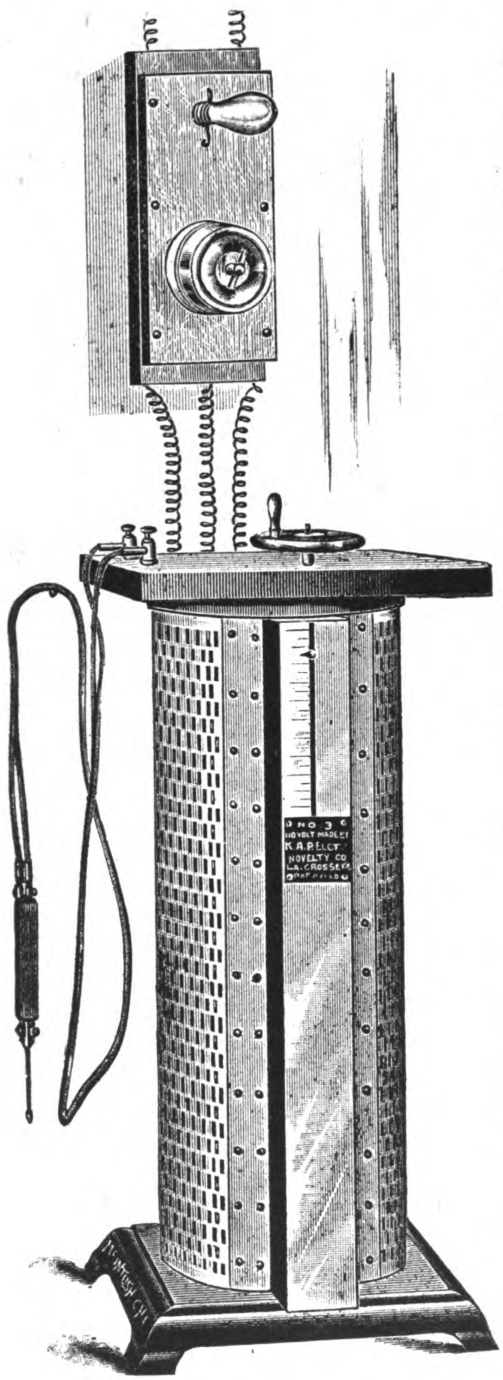
Effects Upon Protoplasm.—The formless cell contents of living tissue, that substance in which all life processes take place, is seen to be directly changed in form by currents that are not strong enough to rend apart its complex molecular combinations. The nucleus of the cells can be seen to change position with reference to the cell protoplasm, and experience proves that cell activities are quickened or depressed and nutrition modified by the employment of continuous currents

to a greater degree than by any other form of electric energy as yet employed in therapeutics. Experience must yet determine when and by what methods the action of the current upon cellular life processes is beneficial or otherwise.

Primary Battery Tests.

The tests of efficiency and durability of certain forms of primary batteries which we have been conducting in this Laboratory for some months past, according to a plan already published in the BULLETIN, are still in progress. Many of these batteries are long-lived when used only on therapeutic work, and as it is our purpose to run them down in the test the work will, in all probability, not be completed for months to come. A full report of these tests by reason of its bulk cannot appear in the columns of the BULLETIN, but a record of all the observations made up until the 20th of June has been sent to each manufacturer who submitted specimens of batteries for examination. The Director of the Laboratory wishes to be informed if any of these copies have not reached those entitled to them. A final report will appear in these columns when the work is completed.

The K. A. P. Dynamic Cautery Apparatus.



This instrument was sent to the Laboratory for examination by the McIntosh Battery and Optical Co., of Chicago. It is designed to be used on incandescent circuits for the purpose of heating cautery knives and lighting small low volt lamps such as are used by physicians and surgeons for illuminating the passages and cavities of the body.

The advantages claimed for the device are briefly as follows:

It furnishes a constant and inexhaustible electric energy.

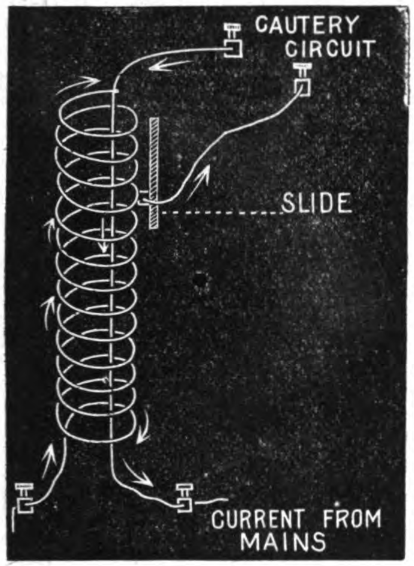
It can be connected with any constant current of 110 volts.

It is regulated with perfect ease so as to light exploring lamps requiring less than 1 ampere of current or heat the largest cautery knife or loop taking from 10 to 20 amperes.

There is nothing about it to wear out.

It is strictly fire-proof. The cost of operating is comparatively small.

The cautery circuit is a shunt off from the main circuit of the instrument and is so arranged that by means of a sliding contact, marked with a scale, it can include in this shunt circuit any resistance from .08 ohms as when the index points



13 at 0, to 1.08 ohms with the pointer at 6. From the nature of divided circuits, the current in the cautery branch of the shunt will be least with the pointer at 0 and greatest at 6.

The greatest resistance of the coil, composing the instrument, is 4.22 ohms and its least resistance i. e. with a cautery of 1-10 ohm in circuit and the index pointer at six, is 3.23 ohms. It follows from Ohm's law that the least current furnished to the instrument, under the conditions named, will be $\frac{110 \text{ volts}}{4.22 \text{ ohms}} = 26$ amperes and the greatest current $\frac{110 \text{ volts}}{3.23 \text{ ohms}} = 30.4$ amperes. The latter is the case when the largest possible current is passing to the cautery which would be 27 + amperes.

The currents in both the main and cautery circuits will be greater or smaller than the above figures according as the resistance of the cautery circuit is less or greater than 1-10 ohm.

The wiring and safety fuses must be especially prepared along a circuit that is to carry a current varying from 26 to 30 amperes and yet no mention is made of this necessity. Unless such precaution is taken the inevitable result must be the melting of the fuses, a matter which might occasion great inconvenience, unless an external resistance sufficient to keep the current below the carrying capacity of the wiring be placed in circuit. Experience shows that the first of these

alternatives is more apt to take place, especially since no provision is made by the manufacturer for the extra resistance.

The manufacturer's circular states that the instrument should have a supply current of 15 amperes for the heaviest cautery work. Should the supply current be in any way reduced to 15 amperes it is evident that the cautery current cannot exceed the supply current and hence it could not heat a cautery requiring 20 amperes of current.

The cost of operating is proportional to the supply current and not to the current in the lamp or cautery, and would be from 26 to 30 cents per hour. This is, however, of minor importance since the current is used only for short intervals.

The current with which the tests were made enters the laboratory with a voltage of 500 and by introducing heavy wire external resistance the supply current strength was 20 amperes. The current in the cautery circuit varied from a small fractional part of an ampere with the index pointer at 0 to 13.6 amperes with the pointer at 6.

The endless screw movement and wheel crank by which the resistance in the cautery circuit is varied is far too slow to meet many of the conditions in practical use of cautery instruments where a rapid variation of current is often required.

The American Electro-Therapeutic Association.

The fourth annual meeting of this Association was held at the Academy of Medicine, New York City, Sept. 25, 26 and 27. Our limited space allows but brief mention of the proceedings. The papers and proceedings were for the most part of a very high order, and challenge the attention of all interested in electricity, medicine or surgery.

The President of the Association, Dr. W. J. Herdman, of Ann Arbor, Michigan, stated in his address that it was a part of the function of the Association to improve and standardize electro-therapeutic apparatus, to aid in harmonizing electrical nomenclature and to assist in the adoption of elec-

trical measurements applicable alike to physics, physiology and therapeutics. By appointing each year committees, whose duty it was to report on special scientific questions, it had been possible to accomplish a vast deal of systematic work, which must inevitably prove in time of great aid and benefit to the general profession.

Dr. William James Morton, of New York, Chairman of the Committee on Standard coils, stated it as his opinion that an induction apparatus suitable for the needs of any physician would comprise, (1) a standard cell; (2) a primary coil of half an ohm resistance, made of No. 22 wire; (3) a vibrator of the reed type; and (4) a secondary coil of No. 32 wire, about five hundred metres in length. Such a coil would give the two effects required—muscular contraction and sedation.

Dr. A. H. Goelet, of New York, said that an apparatus which would answer the purposes of the neurologist would not be suitable for the gynecologist on account of the much lower resistances encountered in the latter class of work. He therefore believed that to be generally useful a medical induction apparatus should have a combination of coils of wire of different lengths and sizes.

In the discussion which followed, the opinion seemed to prevail that the most suitable apparatus of this kind for the physician would be one having two different coils.

The Committee on Standard Meters presented its report through Dr. Margaret A. Cleaves, of New York. After describing a series of tests which had been made with a dozen or more milliampèremeters of different patterns, the committee recommended that for ordinary use the meter should register up to one hundred milliampères, and should be of the horizontal type. A double scale was desirable on the more costly instruments, and all meters should be re-calibrated once a year. To obtain greater clearness of the scale it was recommended that the meter should read only in one direction.

Physics and Current Distribution of the Constant Current.—Mr. W. J. Jenks, M. A. I. E. E., of New York

City, in this paper gave a historical sketch of the methods of distributing the current employed in the various systems of electric lighting, and also the probable distribution of the current when criminals were executed by electricity. Electricity, he said, was not a source of energy, but only an intermediary agent, and the chief point to be considered in its distribution was the one element of pressure. In conclusion, he offered the suggestion that the varying resistances of the human body might eventually be made a means of diagnosis.

THE PHYSIOLOGICAL EFFECTS OF THE CONSTANT CURRENT.—Professor A. E. Dolbear, of Tuft's College, Boston, then read a paper with this title. He said that in a magnetic field all the molecules were acted upon by a pressure tending to twist them into new positions. Dr. Frederick Peterson, of New York City, and Professor A. E. Kennelly, of Philadelphia, had failed in their interesting experiments with magnets to observe any appreciable effect on the human body, even though the brain were placed in the field of a very powerful magnet. But these experiments did not necessarily prove that such magnets exerted no influence on the human body; in fact, as the brain itself was not a sensitive organ, why should we expect that it would be affected by a powerful magnetic field. The reason these experimenters failed to detect any magnetic effect on the body might have been that the stress was exerted upon the molecules only. A constant pressure producing no muscular movement could hardly be expected to produce a sensation. The author's opinion was that the effect of magnetism was to produce a diminution of sensitivity, and that theoretically the human body might be considered to be a mass of atomic magnets. He would entirely disassociate magnetism and chemical affinity.

ULTIMATE RESULTS OF CONSERVATIVE ELECTRICAL TREATMENT IN GYNECOLOGY—CONSECUTIVE PREGNANCIES.—Dr. George Apostoli, of Paris, sent a communication with the above title. The writer stated that the constant current was often an effective substitute for the curette, not only on

account of the ease with which the degree and extent of the action could be controlled, but because of its microbicidal power. The electrical treatment of uterine fibroids was purely symptomatic, yet with it hemorrhage could be controlled in ninety per cent., the pain relived in eighty per cent., and the fibroids reduced in size in seventy per cent. of the cases. Although his patients came to him at an average age of from thirty-five to forty-five years, and often with fibroids, a very considerable proportion had become pregnant subsequent to the electrical treatment. A detailed account of thirty-two such cases was appended to the paper.

THE ELECTRO-THERAPEUTICS OF DISEASES OF THE EYE.—Dr. L. A. W. Alleman, of Brooklyn, N. Y., read a paper in which he detailed the especially favorable results he had obtained from the use of the constant current, (1) in the removal of eyelashes which irritated the eyeball; (2) in granular conjunctivitis; (3) in stricture of the lachrymal duct; (4) in keratitis and opacities of the cornea; and (5) in retinitis diabetica and retinitis pigmentosa.

THE ACTION OF ELECTRICITY ON THE SYMPATHETIC.—Dr. A. D. Rockwell, of New York, continued the consideration of the effects obtained from the constant current by presenting a paper on "The Action of Electricity on the Sympathetic." The paper dwelt more particularly on the results of his experience with electricity in the treatment of exophthalmic goitre and hyperidrosis.

METALLIC ELECTROLYSIS.—This was the subject of a brief communication from M. Gautier, of Paris, and also of a paper by Dr. William James Morton, of New York. The latter detailed some experiments regarding the diffusion into the tissues of the metal dissolved from the electrode. He had found that the apple-green color of the tissues after cupric electrolysis was due to an interstitial deposit of an amorphous insoluble salt of copper, and that there was also a soluble salt of copper deposited in the tissues. His experiments had also shown that soluble electrodes might be used with the negative

pole, one of the best metals for such a purpose being aluminum. Among the clinical adaptations of metallic electrolysis might be mentioned its prompt and curative action in trachoma.

A REPORT TO DATE OF THE TREATMENT OF URETHRAL STRICTURE BY THE CONSTANT CURRENT was read by Dr. Robert Newman. The report stated that his further experience had only served to confirm his former statements and observations. In some instances the patients had been kept under observation for eleven years. In proof of his claim he submitted statistics and documentary evidence from practitioners in various parts of the country.

THE BEHAVIOR OF CANCER UNDER MILD GALVANIC CURRENTS.—Dr. R. J. Nunn, of Savannah, reported the case of a lady, aged sixty, in whom he had succeeded in greatly reducing the size of the carcinoma of one breast by mild percutaneous applications of the current. She then drifted away into the hands of some faith curers. At the time she left him the tumor measured two by two and a half inches, but on her return to him five months later it measured fully thirteen inches in circumference, and there were secondary deposits in the other breast, and in the pelvic and abdominal viscera. The treatment was resumed, and with benefit, but she eventually died of the disease. His special object in reporting the case was to show the effect of such mild currents in a case in which the diagnosis of cancer was beyond a doubt.

HYDRO-ELECTRIC METHODS, PHYSICS AND APPLIANCES.—Mr. H. Newman Lawrence, M. I. E. E., of London, Eng., read the paper. After speaking of the importance of using well made and carefully installed apparatus, he stated that nothing surpassed the electric douche for giving the maximum of concentration and localization of the current with the minimum of pain, and expressed the belief that it was particularly suitable for the electrization of the internal cavities of the body. The resistances to the current increased greatly as the temperature of the water decreased. In the bipolar bath only a small proportion of the current passes through the patient.

A communication was then read from Dr. W. S. Hedley, of Brighton, England, on this subject. He said that the temperature of the bath should be between 90° and 104° F., and a faradic current should be allowed to flow for a few minutes before the patient leaves the bath. He had obtained his best results with this treatment in rheumatoid arthritis.

Dr. M. A. Cleaves followed with some remarks on this subject. She described Boudet's excellent method of treating occlusion of the bowel, and exhibited electrodes for making such applications to the bladder, rectum, pelvic tissues, ear and nose. This was the most important method of employing cataphoresis, and perhaps in no disease was its good effects so apparent as in the treatment of gonorrhœa by hydro-electric applications.

THE EFFECTS OF HIGH FREQUENCY DISCHARGES.—Professor Elihu Thomson, M. A. I. E. E., of Lynn, Mass., sent a communication on this subject, in which he stated that if a person were subjected to a current of over ten thousand alternations per second, and a voltage of one hundred or two hundred thousand, comparatively little sensation would be experienced, although the heating effect might be sufficient to bring a 110-volt incandescent lamp to full brilliancy. Its comparative harmlessness he had demonstrated to be due not to its physical properties but to physiological peculiarities of the nerves of the human body.

SOME EXPERIMENTS ON DEATH BY THE ALTERNATING CURRENT.—Professor Edwin Houston read a paper, prepared by Professor A. E. Kennelly and himself, on this subject. The object of the experiments was to refute the startling assertion made by M. D'Arsonval that the criminals condemned to death in the electric chair were not really killed by the electricity, but subsequently by the *post-mortem* examination. Their experiments seemed to show that at least in the case of dogs, where electrocution was properly carried out, there was not even a remote possibility of subsequent resuscitation, and that death was instantaneous and painless.

THE TREATMENT OF NEURITIS BY THE GALVANIC CURRENT.—Dr. Landon Carter Gray, of New York, read a paper with this title. He advised waiting three or four weeks if a motor nerve were involved, or if a sensory or a mixed nerve were affected, until the pain had entirely subsided, and then experimentally and very carefully apply a galvanic current of from one quarter to one milliampère. It was important to use a broad electrode above and beneath the affected nerve, and to use a reliable rheostat and milliampèremeter. The discussion seemed to show a general unanimity of opinion regarding the recommendations made in the paper.

SINUSOIDAL CURRENT.—Dr. J. H. Kellogg, in treating of the "Physiological and Therapeutic Effects of the Sinusoidal Current," stated that with fourteen thousand to sixteen thousand alternations per minute he had observed a decided diminution in the sensibility of the parts to which the current was applied, so mnch so that in ten minutes the strength of the current could be doubled without producing increased sensation. He considered the faradic current in every way inferior to the sinusoidal current.

Dr. Hall-Brown described a method which she had devised for controlling and regulating the sinusoidal current as obtained from certain electric lighting circuits. Almost any induction coil would make a suitable transformer for this purpose, but such an apparatus was preferably constructed of one layer of No. 20 wire for the inside coil and ten layers of the same wire for the outside coil.

Dr. William James Morton, Chairman of the Committee on Standard Electro-static or Influence Machines, reported that the committee recommended that the smallest machines of this class intended for medical work should have at least six revolving disks twenty-eight inches in diameter, instead of four disks, as recommended last year. It was considered necessary that the machine should have an enclosing case, and highly desirable that there should be a small separate exciting machine within the case, and also an arrangement for producing the static induced current.

Dr. A. Lapthorn Smith, of Montreal, was elected President, and Dr. Emil Heuel, 352 Willis Ave., New York City, Secretary for the ensuing year. Toronto was chosen as the next place of meeting.

A full report of the papers and transactions of the Association will be published in book form, and can be obtained upon application to the Secretary.

Notes.

The National School of Electricity.

We have recently had the pleasure of a visit from Dr. J. Allan Hornsby, Secretary of the National School of Electricity. For the short period of its existence, this school has had marked success in effecting local organizations and securing pupils in many cities and towns both in the West and East. The favor with which its plans and methods have been received by all classes of men interested in the science and practical applications of electricity, has fully justified this departure from the customary routine of educational work. The electro-therapeutic branch of the work already shows vigorous growth. Several physicians' classes are in progress in Chicago. Others are being arranged in New York, Cincinnati and elsewhere, and with these the purpose seems to be to give thorough fundamental instruction in the physics of electricity, and make the pupils familiar with the machinery they will need to generate and control the force, preliminary to the study of its therapeutic applications. All who have had much experience in electro-therapeutics will recognize the wisdom of this plan of instruction.

Does Electrocution Kill?

The following statement of D'Arsonval, taken from the *Archives d'Electricité Medicale*, July 15, 1894, is of interest in view of the fact that the opinions of this noted biologist on the matter of "electrocution," as practiced in some parts

of this country, have received quite an airing in the daily papers and scientific journals:

"In my note of April 4, 1887, I showed that electricity produced death in two ways: 1st. By a destructive lesion of tissues (disruptive and electrolytic effects of the discharge); 2d. By excitation of the nervous centers producing an arrest of respiration and syncope, but without material lesions.

"In the first place, death is definite; in the second, only apparent. I have proved that it is possible to recall to life one struck by lightning by practicing artificial respiration. From a number of experiments I have deduced the following practical formula: A person struck by lightning should be treated as one drowned.

"Relying on these facts I oppose the kind of death applied in America under the name of 'electrocution;' the industrial alternating currents employed in this case producing nearly always the second kind of death.

"An accident a few days ago, the conditions of which could be determined with all the accuracy of a laboratory experiment, confirms on man what I have seen with animals. Picou and Maurice Leblanc, two well-known electrical *savants*, were eye witnesses."

Professors Houston and Kennelly, of Philadelphia, have recently conducted an elaborate series of experiments on animals, hoping to throw light on the question of actual death here in question. Their report, read at the recent meeting of the American Electro-therapeutic Association, seems to prove conclusively that electric currents such as have been employed for purposes of "electrocution" in New York have caused "definite" or somatic death.

Governor Flower of New York is reported as expressing a willingness to permit efforts at resuscitation to be made by a competent committee upon the next criminal condemned to death by electrocution in that State.

VOLUME II. JANUARY, 1895. NUMBER 1.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN

Published Quarterly by Register Publishing Co., Ann Arbor, Mich.
Subscription Price One Dollar a Year.

Catalysis.

It is due to the teaching of R. Remak, previous to his premature death in 1865, that the word catalysis found a place in electro-therapeutics. It was employed by him as a convenient term under which to include the various processes, partly demonstrable and partly theoretical, which attended the application of the direct or galvanic current to diseased tissues and which often resulted in a restoration of normal function. These processes, we are now prepared to believe, are of a complex nature. Certain of them we know to be physical while others are physiological. We have endeavored in preceding articles to direct attention to some of the actions which are always present to a greater or less degree in the tissues of a living animal organism whenever a direct electric current is passed through them. Thus we have discussed electrolytic, cataphoric, contractile, and electrotonic action each of which has its part to play in bringing about the improvement that has been clinically demonstrated over and over again in therapeutic applications of the direct current.

But no one of these classes of action nor all combined are sufficient to account for the permanent benefit which the employment of such currents in therapeutics affords. It is assumed therefore that there are a variety of effects not yet experimentally demonstrable but still theoretically quite probable, that follow from the passage of the current in addition to these that can be readily observed, and it is both these known and assumed actions that the word catalysis is intended to cover.

When we were considering the electrolytic action of the direct current and the polar phenomena due to it and the therapeutic applications of this polar action both anodal and cathodal, intimation was given that electrolytic effects occurred in all probability, at points in the tissues remote from either pole or electrode but in the course of the current between them. The separation of the *ions* at the electrodes must of necessity cause some change in the molecular arrangement of the substances which give up those *ions*. In a liquid of simple composition with a uniform resistance throughout it, that which occurs is generally explained by the theory of Grothüss or Clausius which assumes that the interpolar molecules remain the same in composition but that by reason of the loss of atoms at the electrodes by electrolysis the atoms of these intermediate molecules are forced to change partners and so a rearrangement takes place all along the line. This is very simple and easily understood when we are considering a liquid substance of simple composition, as water, but what may occur by reason of the passage of an electrolizing current through the exceeding complex solutions and varying resistances met with in the tissues of a living animal organism is not so readily followed.

A simple experiment may serve to illustrate the first step in this intermediate whirl of activities. Let as many as six or eight small beakers be taken and each be partly filled with a neutral solution of sodium sulphate, then add a few drops of an alcoholic solution of phenol-phthalein to the contents of each beaker. Arrange the beakers in a row and connect the fluid in them by bits of copper wire. Into one terminal beaker insert the anode of a continuous or direct current circuit and

into the other terminal beaker the cathode. If the current which passes has but the strength of one milliampere a violet discoloration will soon be observed about the tip of copper wire in each beaker which lies nearest to the cathode and which is, in fact, the cathode for that cell or beaker. This color indicates that the sodium sulphate has been decomposed and the soda set free at the cathode has reacted upon the phenol-phthalein; a double chemical action, one destructive, followed by another that is constructive, occurs in each cell as a result of the presence of the electric current.

It is no imaginary conception that is indulged in when a resemblance is pointed out between this simple arrangement and the conditions present in the tissues of an animal organism. The fluids in the latter may be more complex and the connections between them, that is, the various tissues—may be better or poorer conductors than the bits of copper wire, but with the exception of a much greater complexity in the composition of the electrolytes and the intervening conductors the conditions remain essentially the same. If electrolytic decomposition is not seen to take place it is either because we have not known how to seek for it or because the reconstructive chemical or vital combinations have taken place so promptly as to hide the first steps in the process. It is therefore only from the ultimate physiological or therapeutical results that we can form an estimate of what occurs in this secret laboratory.

Cataphoric action also leads to secondary processes. It aids in conveying liquids and the substances dissolved in them into and away from tissues and although we cannot yet say in any particular pathological condition just what the secondary chemical, mechanical or vital changes are which the cataphoric action induces yet it must appear evident that the change in conditions that it brings about must result in something different from what would have been the case had the cataphoric action not been employed.

So with the direct and indirect physiological reactions which the current occasions in living animal tissues, each one,

muscular contraction, nerve stimulation or sedation, and the excitation of cell protoplasm is attended by a train of sequences which have their part in modifying nutrition.

Trophic changes may be directly set up by action upon the cell contents or indirectly by modifying the conditions under which nutritive activities are carried on. Until the organic chemist, the physicist, the physiologist and the pathologist can trace out for us the intermediate steps through this labyrinth of activities which lies between the first effects that we can demonstrate as resulting from the application of a direct current to living tissues and the final results which clinical and physiological evidence though somewhat conflicting in details, still positively assert follow from such applications, as the increase of growth, increased functional activity, removal of abnormal deposits, etc., we will find it convenient to refer to this series of changes under the one comprehensive term *Catalysis*.

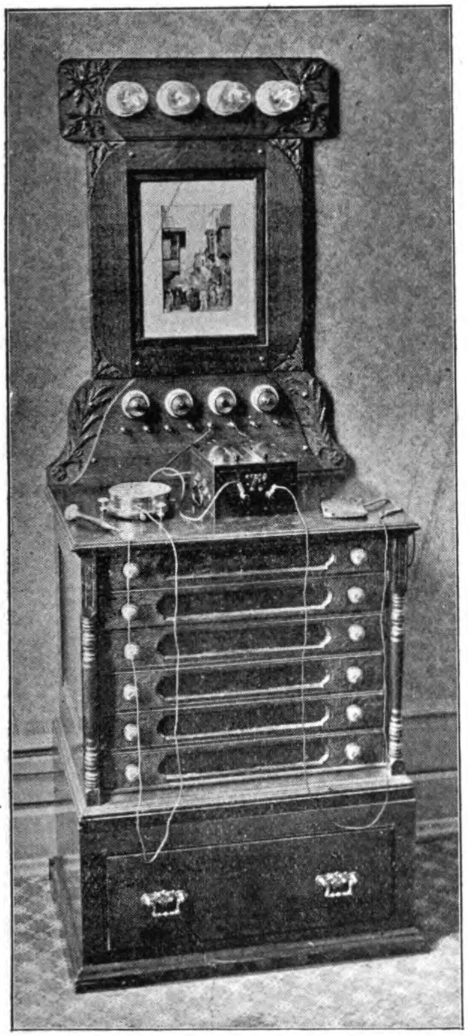
A Convenient Outfit.

Simple, efficient, and time-saving apparatus is what commends itself to the busy physician. When he is once convinced that electricity will be of service to him in his practice, the next consideration is to have that servant neat, orderly, well-trained, and prompt to respond to all demands.

He who can will dispense with primary batteries as a source for current and avail himself of the dynamo currents. Some form of dynamo circuit is now in use in the majority of cities in this country, even those of but a few thousand inhabitants, and can be utilized by the physician for his office work, at least. The illustration represents a very compact, simple, efficient and not unornamental design for an electric outfit which was constructed for this laboratory and has been in use for some time and which gives entire satisfaction.

There are four switches at the base of the upper part. Each switch serves as a faucet to turn on a special form of current. From left to right the first switch is connected with

a group of four Leclanché cells which can be placed at any convenient place near at hand; in this case they are in a closet a few feet away. The second switch is connected with the Thomson-Houston dynamo circuit which supplies the incandescent lamps by which the office is lighted. This is an alternating current with 124 alternations per second and an electro-motive force of 52 volts. The third switch is connected with a circuit leading off from a direct current dynamo which provides power for a number of motors. The electro-motive force on this current is 500 volts, but before it reaches the switch the current passes through four 100-volt incandescent lamps which are seen at the top of the frame arranged in series. The fourth switch, the last at the right, is connected with a series of 30 Leclanché cells to be used as a source of supply for a direct current in case the direct current dynamo is not running. Here we have "on tap" electric energy in a variety of forms, and all that is further needed are instruments for controlling, transforming, and measuring it and conveying it to the patient. These are kept in the drawers of the case below the row of switches. The small drawers contain electrodes adapted to every variety of treatment, and the large



drawer at the bottom holds the induction coils, controllers, transformers, and milliampèremeters. A McIntosh current controller can be attached to the binding posts under switches two or three, and by means of it either the alternating or the direct dynamo current may be modified at will and adapted to the therapeutic requirement. When this controller is connected with the binding posts of switch three that is of the direct current, an induction coil placed along side of it can be supplied from the controller with any necessary amount of current to keep it in action, or the induction coil can be supplied with current from the binding posts of switch one. A Wotton or Woakes transformer can be attached to the binding posts of switch two and by means of them this current can be made to heat a cautery of any size, or light an illuminating lamp for exploring the cavities of the body, as the nose, throat, or bladder. The current of the series of Leclanché cells brought to the binding posts of switch four serves as a reserve force in case of need, but in fact it is seldom called upon to do any work since the dynamos are in action during ordinary office hours.

With an electro-therapeutic outfit of this kind, the use of this agent in practice gives genuine satisfaction both in handling it and in witnessing the good results that can be brought about by means of it.

Electric Treatment of Chronic Rheumatism.[1]

By Dr. A. Massy, of Bordeaux, France.

The electric treatment of chronic rheumatism should be divided into general treatment, that of the patient, and local, that of the disease.

General Treatment.—This treatment should be effected by either the static or alternating currents.

(a) *Static.*—The patient should be placed on an insulating stool in communication by means of a metallic conductor

[1] Archive D'Electr. Med., Nov. 1893.

with an electro-static machine furnishing a current of high intensity and negative. Sparks should be drawn from all parts of the body of the patient and more especially from the length of the vertebral column as well as from the joints if the rheumatism be at all subacute. If the condition is more or less acute the sparks should be replaced by friction, practiced especially along the length of the column and over the articulations. The sitting of franklinization should be effected at first by means of the static current alone, then by means of the static current with sparks or friction, finally by means of the static current alone. The total duration of the sitting should be from 20–30 minutes. The sparks or friction should be employed during two-thirds of this time.

(b) *Alternating Currents.*—To be entirely traversed by this current the patient should be submitted either to the method called hydro-electric or to that called auto-conduction.

(1) In the hydro-electric method the current is introduced directly into the water in a bathtub in which the patient is placed. The electric bath may be mono- or bi-polar. We give the preference to the bi-polar bath, with the modification that Gardner has introduced with the object of making the current pass uniformly through all parts of the body. The method is as follows: The patient gets into a circular diaphragm which is placed in the middle of the tub; the space between the diaphragm and the body of the patient is filled with cushions stuffed with bran. The alternating current used for the bipolar bath is furnished by two sources, principally: 1st, by a dynamo for an alternating current; this current should be conducted by means of multiple conductors under a potential suitable for medical purposes (250 ma. and 110 volts at the maximum); 2nd, by the special alternator of d'Arsonval, of which the extra-rapid alternation (10,000 a second) should be used.

(2) In auto-conduction, recently highly praised by d'Arsonval, the alternating current, which should circulate in the patient, does not reach him by means of conductors. It takes its origin in his own tissues, playing the rôle of an induced

current confined in himself. D'Arsonval obtained this result by placing the patient in a magnetic field, oscillating with a very high frequency. This oscillating magnetic field is produced in the following manner: On a cylinder of insulating material (pasteboard, wood or glass) one or more layers of carefully insulated wire from a light is wound. A sort of solenoid is thus made in the interior of which the patient is placed while being electrized. This solenoid is traversed by a discharge from a condenser rendered oscillatory by special processes of d'Arsonval. When impossible to use either the static or alternating currents general faradization, galvanization of the cord, and galvanization of the sympathetic may be employed in the order named. Their effects are, however, limited and uncertain.

LOCAL TREATMENT.—The various electric methods can be employed in this treatment of chronic rheumatism. But they ought not to be prescribed in a general way. We think, chronic rheumatism not being uniform in its morbid maifestations, its electric treatment ought equally not to be uniform in its applications. Following are the electric methods indicated in each form of rheumatism:

(a) *Simple Chronic Rheumatism.*—Electric treatment has to combat several morbid phenomena here.

(1) *Pains on Pressure of the Joints, More or Less Severe, but Always Subacute.*—Stabile galvanization of the joints should be practiced, the current passing through the joints and their vicinity. The positive pole should be placed on the most painful part of the joints. The intensity of the current used should be from 10–30 ma. and the duration of the electric sitting from 10 to 20 minutes.

(2) *More or Less Marked Difficulty in Movements of the Joints.*—From the first, as in "1," stabile galvanization of the joints should be employed for about 10 minutes. Following this employ labile galvanization of the same. Apply the current to the muscles and nerves adjoining the articulation, using the negative pole especially, and making a number of interruptions and commutations of the current.

(3) *Pains, Muscular and Neuralgic in Parts Adjacent to the Joints.*—Use the stabile galvanic current at the limits of the painful parts, by means of the positive pole entirely, for about five minutes, and of an intensity of 15–30 ma. Also faradize these painful parts, doing this with a metallic brush with an energetic current (a fine coil and extra rapid interruptions). Each application of the faradic current should be short—2–3 minutes.

(4) *Muscular Atrophy Localized in the Parts Adjoining the Articulations.*—Employ the continuous current on the atrophied muscles by means of the negative pole. Some interruptions of the current as well as commutations will be of service. The intensity should be from 15–30 ma., the sitting from 10–15 minutes. The faradic current can also be used. If so, apply this current (coarse coil and slow interruptions) on the atrophied muscles from 15–20 minutes. For the treatment of this muscular atrophy we advise galvanization from the first, galvano-faradization following, and finally simple faradization. We think the atrophy will succumb more rapidly to an electric treatment thus combined.

(b) *General, Chronic, or Nodose Rheumatism.*—The special form of electro-therapy of this form of rheumatism will be that of the various morbid phenomena which characterize it and which are the following:

(1) *Articular Pains.*—A stabile galvanic current should be passed through the joints. The positive pole should be placed on the most painful parts. Intensity from 15–40 ma., duration of sitting from 15–20 minutes. Faradization (fine coil and extra rapid vibrations), either dry or moist, of the joints may be practiced from 3–4 minutes, with a moderately strong current.

(2) *Muscular Contracture.*—This should be treated with the continuous current, the faradic being used only when no results have been obtained with the preceding. The continuous current should be applied in two principal ways, which we will describe in the order of their therapeutical value: The first consists in a stabile application of the positive pole over

the portion of the spinal cord governing the contractured muscles. The negative pole should be placed over the muscles themselves. The intensity of the current should at first be very feeble, about 10 ma., then it should be increased gradually to 30 ma., finally it should be very gradually decreased. The time of the application of the current to the contractured muscle should be from 10–15 minutes. The second includes the use of the stabile descending currents directed through the muscles and motor nerves. The intensity should be high, 30–40 ma., and the time about 10 minutes. Some interruptions and commutations of the current may be made at the close of the sitting. The faradic current should be used in three principal ways, described in the order of their merit: The first consists of the faradization of the antagonists of the contractured muscles. The faradization should be accomplished by means of a sufficiently strong current (coarse coil and very slow interruptions) acting 2–3 minutes on each antagonistic muscle. The second comprises the use of strong and increasing faradic currents (fine coil and rapid interruptions) during 3–5 minutes on the contractured muscles themselves. The third, finally, consists in the use of the faradic brush (fine coil and extra rapid vibrations) applied over the contractured muscles for 2–3 minutes.

(3) *Shortening of the Extra-articular Ligaments and Tendons.*—Apply the continuous stabile current over the joints and shortened parts near them from 10–15 minutes with an intensity of 20–30 ma. Some interruptions and commutations may be made at the close of the sitting.

(4) *Muscular Atrophy.*—Same treatment as advised for simple chronic rheumatism.

(5) *Swelling of the Articular Ends of the Bones.*—Use either simple galvanization of the joints or electric cataphoresis; but the former always in preference to the latter. The galvanization should be made with a pretty strong current (30–50 ma.) applied in a stabile manner over the joints by means of large moist electrodes. The duration of the application of the current, which ought only gradually to attain its maximum

intensity, should be from 10–15 minutes. The electric cataphoresis should be practiced in the following manner: Apply large sponges of a moderate fulness dipped in a solution (K I & c) on both sides of a joint and pass the current by means of carbon electrodes resting on the same sponges. The continuous stabile current should be used. Endeavor to use an intensity of 80–100 ma. but very slowly and gradually. The tolerance of the patient must always be the only guide to the intensity possible and to be used. The positive pole is to be placed at the side of the most swollen extremity of the bone. Duration, 10–15 minutes.

(c) *Chronic Partial Rheumatism.*—The morbid phenomena are nearly the same as those of chronic generalized rheumatism, with this difference, that in this they are localized. They call for the same treatment as those of generalized rheumatism. Finally, the principal morbid phenomena of partial rheumatism (which consist of deformities of the joints by fluids in them, foreign bodies, bony vegetations, swelling of the epiphyses, and in chronic rheumatism of the phalanges by bony nodosities greatly increased in size) should be treated more especially by electric cataphoresis as described above.

(d) *Chronic Fibrous Rheumatism.*—The morbid phenomena of this variety consist entirely of lesions of the fibrous tissue, both intra- and extra-medullary. The lesions should be met by the continuous current employed as in chronic generalized rheumatism.

[TO BE CONTINUED.]

Notes.

There are some unique things in the article entitled *Medical Treatment* in the supplement to Encyclopedia Britannica p. 696, 9th ed., (J. M. Stoddart, New York, Philadelphia, and London) signed by J. W. L., M. D., of New York, of which the following is a fair specimen:

"Franklinic or static electricity (little used) is produced by friction, and bands and plates are constructed of two metals, and attached to the surface of the body at different parts, for the purpose of creating a constant galvanic current in them."

The grotesqueness of this description would be ludicrous if the appalling ignorance which it displays on the part of a member of the medical profession, chosen to write a learned article, was not so humiliating.

In justice to the medical profession of Gotham, in the face of such mortifying absurdities, it should be said that no where in the world has the value of static electricity been so clearly demonstrated as it has by certain of the practitioners of New York City.

Questions From Correspondents.

"If the medicinal substance is placed upon the cathode would any of it be taken up by the tissues and if so to what extent?"

"In the treatment of goitre and mammary tumors where you desire to secure the clinically liquefying action of the cathode and at the same time introduce into the tissues a medicinal agent, which sponge would you medicate or what course would it be necessary to pursue to attain this end?"

These questions refer to the cataphoric action of a direct or galvanic current and ask for information concerning the behavior of remedies in general when they are subjected to this method of medication. The manner in which any particular remedy will act when the attempt is made to introduce it into the system by cataphoresis must be determined by trial. There are certain substances that are conveyed into the tissues by

means of the anode, others by means of the cathode, while there are still others that seem to be indifferent to the action of either electrode and are incapable of cataphoric transmission. There are only a few remedies the cataphoric action of which has been positively determined. Cocaine hydrochlorate, aconitia, helleborin, lithium chloride, mercuric bichloride, and strychnia nitrate are known to be susceptible of anodal cataphoresis while sulphur and eosine are conveyed into the tissues by means of the cathode.

The action of potassium iodide and of iodine alone in this respect is still in controversy. There is much experimental testimony in favor of the view that molecules of potassium iodide as such are conveyed into the tissues by means of the cathode. While experimenters of equal authority declare that this remedy has been introduced by "anodal diffusion." As iodine or potassium iodide are remedies very likely to be chosen for cataphoric medication an early settlement of this mooted point is important.

In the treatment of a part such as the thyroid or mammary gland where both electrodes can be placed near together and so include between them the abnormal growth one need not wait for the settlement of this question of the selection of the proper electrode, since under these circumstances the medicated solution might be placed in contact with both electrodes and if the remedy is one capable of being conveyed into the tissues cataphorically this will occur at either anode or cathode.

Lightning as a Homicide.

Among the many interesting "Circulars of Information" put forth by the Department of Agriculture, those emanating from the Weather Bureau are often of special interest to physicians. A recent one on "Protection from Lightning," by Alexander McAdie, is of this character. The author states in his introduction that the "aim of the paper is to furnish information of practical value to all classes, and especially to farmers, builders and physicians."

The physician's interest in this topic is naturally directed to the frequency of death by lightning and the manner of it. The Weather Bureau records during the four years closing with '93 show an annual loss in the United States of 196 lives due to lightning, In all probability the actual loss of life from this cause is much greater. But in the light of recent experiments with high potential currents of electricity, oscillatory in character, which are presumed to similate the lightning discharge, a reasonable doubt may be entertained that many of those reported killed by lightning need have died if proper means had been promptly used for their resuscitation. There is no question but that high potential alternating currents of electricity may cause somatic death of the body, yet this result is not so firmly established, either with regard to lightning or those discharges which escape from electric machinery of man's devising, that we can afford to ignore the excellent advice of both McAdie and d'Arsonval that victims of such accidental shocks should be given the benefit of the doubt, and measures be promptly and vigorously made use of to restore the respiration and circulation that would be proper in a case of drowning.

Induction Current Action on Ganglion Cells.

To determine whether there are any modifications produced by electric excitation in the nerve cells of the sympathetic ganglion, M. Lambert has made a series of experiments on the sympathetic ganglion of the rabbit or the young cat.

In the experiments the animal was bound without being anæsthetized. The ganglion and lower portion of the sympathetic for a length of some centimeters was exposed, care being taken not to injure them. Then one of the nerves was excited by means of the induced current from a Du Bois-Reymond coil. The ganglions were then rapidly extirpated, placed in a fixing solution, imbedded in paraffine, then cut and colored by means of various reagents. In one experiment the ganglions were not extirpated till after the death of

the animal, obtained by a subcutaneous injection of cyanide of potassium while the excitation was continued.

The protoplasm of the cells of ganglions not excited is very granular, the granulations being irregularly distributed throughout the cell. Sometimes, however, they are more compact near the periphery. The nuclei, to the number of two, are generally of a quite clear outline, occupying a situation somewhat in the interior of the cell.

Lambert's observations seem to show that the electric excitation of these cells produces a displacement of the nuclei and granulations towards the periphery.—Arch. D'Elect Med., June 15, 1894.

Apostoli's Semi-Annual Publication.

We are in receipt of a copy of Parts I. and II., Vol. I., of *Travaux d' Electrotherapie Gynécologique, Archives Semestrielles d' Electrotherapie Gynécologique*, established and published by Dr. G. Apostoli, Paris, France.

In the author's preliminary statement as to the scope of the work, he says he has undertaken to collect all that has been done on this subject in the last seven years in order to extend the knowledge of it and give to the science of gynæcological electrotherapy a definite basis.

This first volume contains foreign works which will be continued in the next, the French works finding their place later.

Apostoli contents himself with annoting by means of foot-notes, where he thinks it necessary to modify or correct opinions.

The most complete works, those best adapted to convince the ignorant or prejudiced, are published first *in extenso*. Then the works of various observers are taken up in the order of their appearance, the older first with the later opinions ranged in line.

The amount and character of the work contained in these volumes, taken as it is from many and high sources, render it a very valuable contribution to the literature of gynæcological therapy, and we cannot but feel grateful to Dr.

Apostoli for the thorough and impartial manner in which the experiences of so many workers have been collected and made available.

When all the past works are collected, the author intends to continue the *Archives* annually, collecting the new work as it appears. A bibliographical index is to be annexed.

New Static Electrode.

Dr. Lucy Hall-Brown, of Brooklyn, N. Y., has designed a new form of static electrode of which she speaks as follows:

"It is an electrode for general treatment. There is not the slightest danger of a spark jumping from it and yet the spray may be localized at any point or part of the patient's body.

"It is a stick of ash three-fourths of an inch in diameter and three feet long; dull-pointed at one end and terminating in a handle or wooden ball at the other.

"The stick after being nicely smoothed with sand-paper is covered with enamel gold paint and when thoroughly dry the paint is pretty well rubbed off by sand-paper but leaving all the crevices of the wood filled with the gold paint. The surface of the stick is then thoroughly covered with shellac. There will be sufficient conductivity in the gold paint remaining in the crevices and grain of the wood to carry the static current nicely and yet sufficient cannot accumulate to cause sparking. With this electrode the operator stands well off from the patient and may rub the pointed end on any part of the patient's body—under the arms, behind and on top of the knees, at the throat, in the nose or mouth, around the neck, on the head, etc. The spray is very strong and can thus be localized without danger of the spark. It is an excellent electrode for nervous and timid patients.

"The shellac covers the stick to within three or four inches of the pointed end."

VOLUME II. APRIL, 1895. NUMBER 2.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN

Published Quarterly by Register Publishing Co., Ann Arbor, Mich.
Subscription Price One Dollar a Year.

Diagnosis by Means of Direct or Galvanic Currents.

The reactions of living nerve and muscle to electric currents affords an exact and reliable means for determining the condition of those structures at any time. Although there is some difference in individuals as regards the promptness and degree with which nerve and muscle responses take place, even when no disease or abnormal condition is present, yet the mean of normal or physiological reaction can be readily determined by experience, and any marked departure from it is indicative of pathological changes in the nerve itself, in some nerve center with which it is connected or in the muscle to which it is distributed. Electric diagnosis of nerves and muscles presupposes on the part of the investigator thorough knowledge of the topographical anatomy of the human body and a more than ordinary familiarity with the technique of the electrical appliances.

There is no branch of physical diagnosis that requires finer accuracy in observation, closer attention to details or greater skill in manipulation. As it is necessary in electrical diagnoses to concentrate the current upon the nerve or muscle to be tested in order to differentiate its reaction from others, the active electrode should be small in size and so shaped as to be readily adapted to any surface contour. An electrode terminating in a metal or carbon ball one or two centimeters in diameter, would seem to be best adapted for this purpose; and if a bit of absorbent cotton is twisted about this rounded end of the electrode and moistened it will give in contact all that could be desired. The active electrode should be furnished with a break-circuit handle. The indifferent electrode should be large in size, 10 by 15 centimeters, (4 by 6 inches); so as to avoid current density. When opposite limbs or surfaces of the body are being compared it should be placed with its surface well covered by thoroughly moistened amadou, sponge or other absorbent material, upon some median spot on the body, as the sternum. The pressure capacity of the direct current used should be at least twenty volts, and there should be a milliamperemeter and a pole-changer in circuit, together with some means for modifying the strength of the current, such as a shunt or rheostat.

It is eminently desirable that some association of physicians qualified to act with sufficient authority should adopt rules governing the size, shape and material of electrodes and methods of applying them in electric diagnosis in order that greater uniformity in conditions might be adhered to by different examiners, and serve as a basis for comparison of results.

The use of the direct current in diagnosis is largely dependent upon the reactions that result from its application to nervous and muscular tissue. The action of the direct current on nerve and muscle has been very carefully studied by the physiologist, but his results have been obtained from experiments on lower animals and by direct applications of the electrode to denuded tissues. Conclusions arrived at in this

way can not be strictly relied upon as a basis for electro-therapeutic applications to man. The electro-therapeutist has found it necessary, therefore, to study the physiological responses of nerve and muscle under such conditions as obtain in practice, where one body differs from another in the amount of adipose tissue surrounding the parts to be influenced and where where the skin is always an intermediate obstacle which, together with the other intervening tissues, prevents an exact estimate of the current density that is brought to bear upon the nerve or muscle stimulated. In spite of these varying elements in the problem the responses of nerve and muscle in man have been found to follow a certain order when these tissues are normal and when any marked departure from this normal or physiological reaction to electric currents exists, objective evidence of pathological conditions in these structures is given. Electric tests, therefore, become a valuable resource for discovering the presence of diseased states if they actually exist, as well as for showing that disease is not present when the patient is a malingerer.

Exciting Effects of Direct Currents on Motor Nerves. A motor nerve when stimulated by a direct current of sufficient density manifests its excitation by a contraction of the muscle which the nerve supplies. "It is not the absolute degree of density of the current at any certain moment which acts as an excitant to the motor nerves, but only the change in its degree from one moment to another; i. e., it is only variations in the density which excite, and their action is the more intense the greater the amplitude in a unit of time; or their amplitude being equal, the more rapidly they occur; most intense, therefore, upon the sudden closure and opening of the current." Not only does the degree of excitation of the nerve vary directly at the "make" and "break" of currents differing in strength, but a difference in excitation is also seen according as the current passes in one or the other direction. When we attempt to arrange these reactions of the nerve in a tabular form according to gradual increase of current strength,

we find that the following is the normal order for contractions:

Weak current,	C. C.			
Moderate current,	C. C.	A. C.		
Stronger current,	C. C.	A. C.	A. O.	
Strongest current,	C. C.	A. C.	A. O.	C. O.

C. C. standing for cathodal closing, A. C. for anodal closing, A. O. anodal opening, and C. O. cathodal opening. The first contraction obtained is at the moment of closing the circuit with the cathode for the active electrode. A little increase of current strength will not only give a contraction at the closing of the circuit with the cathode as the active electrode, but by reversing the pole-changer, and thus making the anode the active electrode, a contraction will also be observed at the moment the circuit is closed, the strength of current remaining the same. By still further increasing the strength of current, not only the responses above named take place according as one or other pole is applied to the nerve, but in addition a contraction occurs when the circuit is opened with the anode over the nerve. But as a matter fact, the A. C. does not always precede the A. O. contraction, but may in some cases follow it. Not infrequently these two contractions are equal in intensity. The strongest currents that can be tolerated will cause, in addition to the other three, the C. O. or a contraction when the circuit is opened with the cathode over the nerve, but it is not easy to demonstrate this contraction because of the discomfort due to irritation of the skin and the vigor of the C. C. contraction which must of necessity precede it.

Erb and DeWatteville have each in his text-book on electro-therapeutics attempted a scientific explanation of this order of excitation of nerves upon increase of current and change of polarity. They are practically in accord in their views as to cause of the phenomena.

In making use of this normal or physiological law of responses of nerves to the direct or galvanic current, as a basis for detecting abnormal conditions, departures from the normal, if present in any marked degree, will show themselves by

increased excitability or by *diminished* excitability, and in the latter case may be so far reduced as to give no reaction whatever, which is true when the nerve has lost its conducting power through degeneration or injury.

Increase of nerve irritability in the nerve is observed in some morbid states in which the changes of nutrition in the cells and fibres are extremely slight, though the morbid conditions may remain for quite a long period. Such is the case in certain diseases regarded as functional, and thus increased irritability may be regarded as a proof that molecular changes are present in these functional maladies. Spinal irritation, neurasthenia, chorea, paralysis agitans, and even slight attacks of neuritis may exhibit increased excitability of the motor nerves. It has also been observed in various forms of cerebral paralysis, in recent hemiplegias and at times in the early stages of tabes. Increased electric excitability of nerves has not taken that place in diagnosis that it deserves. A simple exaltation of excitability in a motor nerve in response to a direct or galvanic current is shown by a C. C. contraction with a feebler current than usual; this contraction, by slight increase becomes tetanic; an over prompt A. O. follows the A. C. with comparatively weak currents and with a little stronger current the A. O. causes tetanus of the muscle.

Decrease in nerve excitability in the nerve to the direct current can be determined with accuracy only when we know that the muscles supplied by that nerve are in a normal condition, since the muscular contraction is our index; this is equally true for increased irritability. The nerve, therefore, may be in better state than the electric reaction would seem to indicate, since the muscle may be at fault and cause the increased or diminished response. A direct examination of the muscle will help to make clear the seat of lesion. If there is a diminution of excitability in a muscle manifested when a direct current is applied to a motor nerve and no *qualitative* but only a *quantitative* change in reaction is found in the muscle itself, there is a reason for assuming that the fault is in the nerve or perhaps in both nerve and muscle. Diminished excit-

ability in a nerve to the direct current is shown by a stronger current than usual being needed to get C. C., still stronger for A. C. and A. O., while C. O. may not be obtained; or if it is, the strength of current needed to secure it is unbearable. The separate reactions gradually disappear, as the decrease of excitability progresses. First C. O. is lost, then A. O. and A. C.; and C. C. can be produced only by the strongest currents. When at last the C. C. current cannot be obtained the galvanic excitability of the nerve is said to be lost. Frequently, however, when no response can be elicited through the nerve the *reaction of degeneration* is exhibited by the muscle.

Decrease with final loss of excitability of the nerve is the necessary accompaniment of degeneration of the nerve in its course, at its center, or at its peripheral distribution. Joint affections resulting in disuse of muscles and nerves and reflex disturbances of nutrition at nerve centers cause diminution of excitability. Lowered nerve excitation is also present in long standing cases of cerebral paralysis, and spinal cord affections where the spinal centers are impaired in nutrition by direct disease or over-action as in chronic bulbar paralysis, spastic paralysis or tabes. Pressure paralyses of nerves and some forms of multiple neuritis, as those due to alcohol or arsenic give evidence of decrease or loss of nerve conductivity, at times, before any qualitative change can be detected in the muscles. Impaired excitability of the nerve is, however, usually attended by muscular change.

Action of Direct Currents on Muscles.—Although the motor nerve and the muscle it supplies may be regarded as a physiological unit, since they act as one, and defect in one or the other will impair the function to which they jointly contribute, yet when it is possible to distinguish which is the primary seat of pathological change, or how far that change has progressed in one to exclusion of the other, we have made a step in advance in diagnosis and have cleared the way for a more accurate prognosis and more rational treatment.

We have in the direct current such a means for differential diagnosis based upon the fact that under certain circumstances the muscle responds to this current, when applied to it directly, in a different manner than when the current is applied to its motor nerve.

Quantitative changes in reaction of muscles to the direct current without qualitative changes (reaction of degeneration) do occur, although they are rare. They are in the nature of increased or diminished excitability of the muscle when the active electrode is applied directly to it rather than to the nerve that supplies it. In the attempt to secure the muscle reaction as distinct from that of the nerve, "the motor point" of the muscle, that is the point where the nerve enters it, should be avoided in applying the electrode, otherwise it may still be the nerve reaction that is obtained. Both electrodes are sometimes placed over the muscle in these tests but it is best to adopt the uniform method of keeping the indifferent electrode at some central point, so that comparison can be made with corresponding muscles on opposite sides of the body.

Increase in muscle irritability to the direct current, present in cramp, tetanus, etc., is in all probability secondary to central nerve disorder while the diminished response noticed in pseudo-hypertrophic paralysis is due to the trophic changes beginning in the muscle. Simple quantitative changes in muscle reaction to the direct current are present in the same diseases in which like reactions are obtained from stimulating the nerve. Increase of galvanic irritability is one of the characteristics of the early stages of reaction of degeneration (RD) which will be considered in detail later, and which is attended by a changed order of contractions as well as difference in their character. The reactive changes now under consideration are those only where a less or greater current than ordinary is required to provoke a contraction in a muscle, the character of the contraction remaining short and quick, as in health, and the physiological polar order of contractions being preserved. The muscle showing these *quantitative*

reactions to the direct current in distinction from *qualitative* reactions is one still in connection with its nerve supply, but one in which nutritive activities may be excessively active or sluggish as shown by these responses. It cannot be always determined by the electric tests alone whether this nutritive disturbance has its origin in the muscle or in the nervous structure but the nature of the muscle reaction furnishes valuable evidence in the search for the primary seat of disease.

[TO BE CONTINUED.]

The Jewell Milliampere Meter.

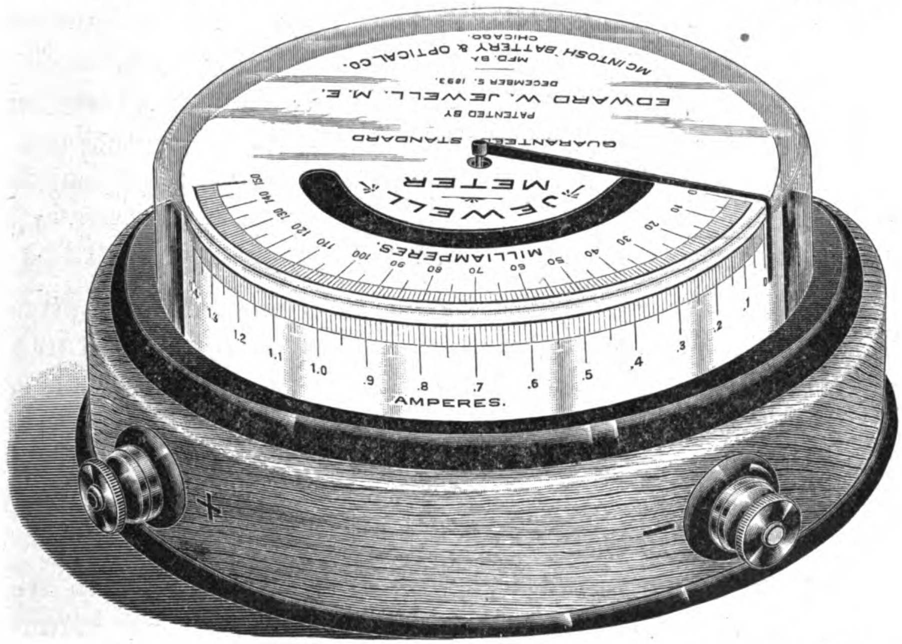
It is a good indication of the progress of scientific electro-therapeutics when the demand for more exact and perfect measuring instruments is on the increase.

The only portable standard measuring instruments which have been found successful in practice, are those of the d'Arsonval type. That is, those is which the actuating force of the index is the current flowing in a coil of wire, which moves in a field of one or more permanent magnets, usually of the horse shoe type. The current is conveyed to the coil by two spiral springs which also serve to resist the motion of index and coil.

The compass-needle class of instruments are too easily affected by the presence of iron or by magnetic disturbances to be relied upon if anything approaching accuracy is desired. One fault which has obtained in the different makes of d'Arsonval galvanometers up to the present has been their liability to inaccuracy owing to the weakening of the permanent magnets.

In the Jewell milliampere meter this fault has been over come by using an improved form of laminated permanent magnet and also by so shaping the pole pieces that the magnetic reluctance (or resistance) shall be exceeding small. At the same time a large travel of index is secured, amounting to 150 degrees of arc, and the scale divisions are uniformly spaced throughout the entire length of the scale.

Two ranges of reading may be had, two different scales being provided, one horizontally and the other vertically placed. To change from one scale to the other the current need not be interrupted. Referring to the figure on the following page, suppose the current to enter the binding post B, the switch S being opened it passes to n, where it divides, part passing through C known as the calibrating shunt to the binding post B, the rest passing through the spiral spring e,



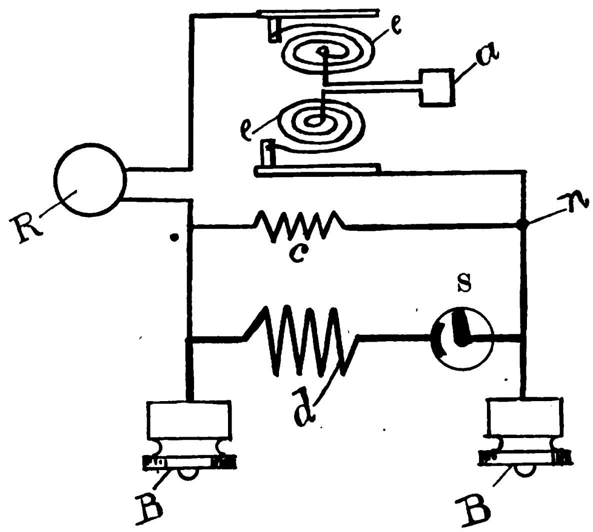
the moving coil a, the other spring e, thence to the binding post B'.

The resistance of the calibrating shunt c, and the moving coil a, bear such a relation to each other that when one milliampere flows from B to B', the index will be deflected one small scale division.

If it is desired to read above 150 milliamperes the switch S is closed. Part of the current will then pass from B through the switch S, and is shunted, to the binding post B′, the remainder passing by the way of c and the instrument coil a to B′.

The resistance of the shunt d, calibrating coil, and instrument coil a, then bear such a relation to each other

that when 10 milliamperes of current pass between the binding posts the index will be deflected one small division. Or in other words closing the switch S diminishes the sensitiveness of the instrument ten times, so that a maximum of one and one-half amperes may be measured. A pole changer is placed in the instrument circuit at R, as shown in the cut, so that current flowing in either direction may be measured without disconnecting the wires from the binding posts. This is a very desirable addition to a meter where the needle moves in but one direction, since it is often needful in electrotherapeutic work, especially in electric diagnosis, to change the direction of the current without disturbing in any other respect the arrangement of the appliances used.



The McIntosh Battery & Optical Company to whom we are indebted for the examination of this instrument, are manufacturing, under the Jewell patents, a complete line of ammeters, volt meters and combined instruments.

The National School of Electricity.

The National School of Electricity, which has occupied a large share of public attention during the last twelve months because of the new educational lines upon which the school was originally organized, will have completed its first year of work the middle of May, and a few facts concerning it and its mission would seem appropriate at this time, as we have received many inquiries from our readers regarding its work. Especially has the school become of interest to physicians in that an attempt has been made in a department of the school to place the science of electro-therapeutics upon a high plane, and to give that science standing not only in the electrical but the medical profession.

Taken as a whole the work accomplished by the school during the year is certainly phenomenal. It began its career with a guarantee from certain gentlemen interested in electricity and education in Chicago and elsewhere, that the finances of the school would be provided. A small amount of money was used in the equipment of the school, the purchase of apparatus, etc., and a very large amount of work on the part of the business managers and the professional gentlemen who compose its educational corps, made up for any shortcomings in the direction of finances. An examination of the books of the school recently made gives the following figures:

The school without respect to departments, has in its classes now operating more than 2,000 students, the receipts from tuitions have been approximately $26,000. Approximately this amount of money has been expended; about $15,000 in organization and teaching, and about $10,000 in apparatus and equipment. These receipts and expenditures have resulted in the organization of more than 80 classes in all departments. The school has an organization to begin its second year's work of twenty thoroughly experienced and carefully prepared organizers, a corps of fifty instructors, besides the members of the honorary faculty who have been engaged in the preparation of the various courses of study. It has now

fully prepared three courses of instruction: one general, comprising 45 lessons; a railway course composed of 32 lessons, and an electro-therapeutic course composed of 30 lessons. All three of these courses start from the same point, going together through those lessons devoted to the elementary principles of electricity, separating from each other only when it is necessary to take up the studies incident to the special courses. Not a small part of the equipment of the school to begin the second year's work is a vast fund of information secured by those who have been in the work during the past year. Conservative and intelligent judgment of those who have been in touch with the actual work of classes of the school, indicates that the standards originally fixed have not only been maintained but that improvements have constantly been made with a view to accomplishing the original purpose of the school, that is, the teaching of electricity in a plain, simple and practical way to those not in a position to avail themselves of more exacting conditions for acquiring this kind of knowledge.

The electro-therapeutic department is, of course, of more interest to physicians, and hence has been followed more closely by the BULLETIN. That work has been as conscientiously done as any similar work of education ever attempted. An inordinate amount of work was necessary for the preparation of the material which entered into the electro-therapeutic studies in the first place, largely because of the scarcity of reliable up-to-date literature, and special effort was necessary to bring the physicist and his knowledge into touch with the physiologist and pathologist, and his special knowledge. The results have more than paid for the work and expense, however, and that department of the school is in a most excellent operating shape to-day. In Chicago, where the first electro-therapeutic classes were organized, there are now 150 physicians taking the course, among them some of the ablest men in the medical profession—professors in the best colleges. The work is also inaugurated and in actual operation in Cincinnati, and all the lines are laid and a large class organized in New York City to begin work in September next. This electro-

therapeutic course consists of fifteen lessons upon the elements and principles of electricity independent of its therapeutic action, and fifteen other lessons upon the physiological effects of the various forms of electrical currents. This course of thirty lessons is intended to thoroughly prepare and does prepare the physician for a supplementary course largely clinical in character, which follows. This clinical course in Chicago will be given by the following men, whose names are an indication of the value of the instruction they will give:

Dr. Brower will teach the uses of electricity in neurology and diagnosis; Dr. Murphy, in surgery; Dr. Martin, gynæcology; Dr. Casselberry, nose and throat; and Dr. Davis, clinical medicine or the uses of electricity in ways not specified in the foregoing special directions. The course of lectures will be about fifteen in number, and will be held at the public hospitals of Chicago, where clinical material will be abundant, and where a vast variety of apparatus has been provided for the purpose. A similar faculty to this has been organized in New York, and essentially the same general course of study will be pursued. In Cincinnati Dr. H. H. Hoppe, a man of special qualifications for the work, is teaching classes through that part of the course previously prepared, and without doubt a faculty similar to those above given will be provided for the supplementary course in Cincinnati.

Special attention has been paid to the physics of electricity in this therapeutic course and instructors with unusual qualifications have been and will be in charge of that work. In New York, Prof. Wm. A. Anthony, known to all scientists in this country, will teach the physical part of the course. In Chicago, Mr. H. G. Brownell, chief instructor for the school, has been and is in charge of the physical part of the work in that city, and in Cincinnati, Prof. Thomas French, Jr., professor of physics in the University of Cincinnati, is the special physicist for the work in that city. Such an organization and such an equipment as this must of necessity carry weight, and that the school in this department has already taken a high

standing among medical men, is ample proof of its future possibilities.

Fortunately for the permanency of the work of the National School of Electricity, it has been kept entirely free from entangling alliances of all kinds. It has not committed itself to the makers of apparatus, the publishers of books or periodicals, and its finances are in such shape that there can be an entire confidence on the part of the public that no short-sighted pecuniary motives will be allowed to creep into the management. A very excellent feature of the school has been the conservative, careful and reliable methods employed at the beginning. No promise of immediate brilliant results has interfered with a very slow, deliberate and conservative progress, and the very able advisers of the school have been unhampered by the business management, and their plans in detail for placing the school upon a high and scientific plane, have been executed to the letter, so that the conditions upon which the school will start out in its second year's work are ideal. No money considerations are actuating the members of the honorary faculty who are directing the work, and the business management of the school has been broad enough to thoroughly appreciate the fact that no permanent success could be achieved unless experienced and disinterested educators could direct the work in all of its details.

The people of this country, especially those interested in electricity in all its branches, and physicians who have at heart the interests of their profession, can congratulate the National School of Electricity on a most auspicious beginning and a more than usually promising future. A year ago the prospectus of the school published in this BULLETIN, proclaimed what the originators of the movement hoped to achieve. They can now point to the fruition of their hopes, to what has been done and what is being done, and they can confidently indulge larger hopes for the future.

Notes.

Developing Muscle by Electricity.

An elaborate series of experiments with the view of determining the effects, beneficial or otherwise, of various forms of electricity on living muscular tissue have been carried on recently by Dr. Debedat, of Bordeaux, France. The account appears in full in the January number of the *Rev. Int. d'Electrotherapie.* The following are his conclusions:—The action of electricity on muscular nutrition is complex; in the form of continuous currents it acts differently than to excite contraction; so far as it excites contraction its action is comparable to that of ordinary exercise, over which it has important advantages from a therapeutic standpoint; moderate muscular exercise caused by rythmic faradic currents, representing natural exercise, produced very marked effects; excitation by rythmic galvanic currents in the form of shocks produced a favorable action, but the action is less than that produced by faradic currents; prolonged tetanization by faradic currents produced an over-working of the muscle followed by a wasting away of the tissue; a static spark produced no permanent modification.

Primary Truths in Electricity.

The physician who desires to draw suggestions from the experience of the electrical engineer may profitably reflect upon a few primary truths which he may have known in the abstract, but which may never have been presented to him as possessing concrete importance.

1. Electricity is not a source of energy but only an intermediary agent.

2. It has one fundamental characteristic by which we make it available, namely—pressure. All its useful engineering results are accomplished by the expenditure of this pressure.

3. By providing a conducting track or circuit of considerable length, two objects may be secured: first, transformation of energy, and second, transference or transmission of energy.

4. Electrical pressure is extended in every part of the circuit (including the mechanism of the generator) in direct proportion to the resistance encountered.

5. It thus becomes possible to transmit and localize the expenditure of the electrical equivalent of an initial mechanical energy with which we start out at any point, or points desired, always considering the inevitable losses which take place in transformation and transmission, and to vary those losses within any limits which conditions of safety and commercial investment may permit.

The engineering practitioner does not recognize in electricity a source of energy. He realizes that to obtain it he must expend some money and can never expect to recover all of what has thus been spent. He is not able to make electricity available to him as a force which directly completes any useful operation. Perhaps the physician can tell whether in the application of electricity to the human mechanism the mysterious agent is itself directly effective, or whether it can be relied upon only to convey to the proper point potent energy so flexible, so obedient to known laws that he can predict the result of its transmission to heat, to chemical action or to some other desired manifestation of what may be, for aught we know, a single, all-pervading energy.—*From a paper by W. J. Jenks, M. A. I. E. E., New York City, read before the Amer. Electro-Therapeutic Asso.*

VOLUME II. JULY, 1895. NUMBER 3.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN

Published Quarterly by Register Publishing Co., Ann Arbor, Mich.
Subscription Price One Dollar a Year.

Diagnosis by Means of Direct or Galvanic Currents.

(CONCLUDED.)

REACTION OF DEGENERATION.

Reaction of Muscle:—At times it is found that the response of muscular tissue to the direct current is not only changed in quantity but in quality and order also. This is the case when, through some defect in nutrition, the muscle undergoes partial or complete degenerative atrophy. The cause of such nutritive change in the muscle can usually be found in the nerve which supplies it or in the trophic centre in the brain or cord from which this nerve takes its origin.

Let it be assumed that a nerve, such as the musculo-spiral supplying the extensor muscles of the forearm, has been injured in its course around the humerus so as to interrupt voluntary control of those muscles. The prognosis as to the recovery of the voluntary power depends upon the severity of

the injury the nerve has sustained and the possibility of repair of structure and return of function. Soon after the nerve has lost the capacity to convey volitional impulses to the muscles the latter will be found to give reactions to the direct or galvanic current differing from the normal in the following particulars:

During the first week there is a gradual loss of excitability. During the second week the excitability increases, but the contractions, instead of being sudden and quick as in normal muscle, are sluggish and prolonged, and even with weak currents the contractions may become tetanic.

In addition to the greater excitability of the muscles and the changed nature of the contractions in them, the order of contractions differs from the normal in that the A. C. precedes or is equal to the C. C. contraction.

These changes constitute what is known as the *reaction of degeneration* (R. D.) in muscles; the sluggish and prolonged nature of the contractions being the chief symptom to be looked for in determining the condition.

These changed reactions of the muscles to the direct current persist either until they have become so far degenerated as to yield no response whatever, or until recovery begins to take place. In the former case there is a gradual subsidence of all irritability. It may be months or even years, however, before the point is reached when strong currents can elicit no response. The A. C. contraction is the last to depart.

If recovery takes place, it is slow and indicates that the nerve connection with the muscles is restored. Gradually the normal order and character of reaction returns. Voluntary power over the muscles may be regained while the muscles are still so far impaired as to give the reaction of degeneration (R. D.)

This same state of nutritive change in the muscle giving the R. D. but without the paralysis or lack of conductability n the nerve, has been observed in some cases of lead poisoning so that it would seem that this changed muscle reaction is not invariably due to an antecedent nerve change.

Reaction of Nerve:—So far we have considered the reaction of degeneration as it manifests itself in the muscle when tested by the direct or galvanic current, disregarding for the moment the behavior of the nerve. After severe injury to a nerve, as in the case assumed above with respect to the musculo-spiral, the nerve irritability, if for a moment increased, is quickly decreased and then is lost to both direct and induced currents. Voluntary power over the muscles supplied by the nerve ceases. The nerve is paralyzed because of the degeneration and disintegration taking place in it. If restoration takes place, voluntary power may be restored, as has been said, before the nerve reacts to either direct or induced currents. When, through stimulating the nerve, reaction to electricity does return, stronger currents are needed to elicit it than is the case under normal conditions. The nerve gradually regains its sensitiveness as regeneration becomes complete. Seldom are any qualitative changes observed in the reactions of the nerves to the direct current, although a few instances have been reported where the A. C. preceded the C. C. with a short, quick response of unmistakable nervous origin. (Erb.)

This behavior to the direct current on the part of a motor nerve and the muscles it supplies after the former has suffered degeneration in some part of its course, presents what is known as the *typical or complete reaction of degeneration.* When it is present it indicates some disease or injury of the motor nerve structure to which the muscular change is secondary. As the trophic centres for the motor nerves and muscles are in the anterior cornua of the spinal cord, or in the brain in the case of cranial nerves, disease affecting these centres or any part of the motor nerves between them and the muscles may, if of sufficient severity, cause the muscles to exhibit this reaction of degeneration. Lesions of the central nervous system above the trophic centres for the muscles produce no such result. The presence of the R. D. is an aid therefore, in determining the location of a lesion causing paralysis; while the time the paralysis has existed in any special case, taken in connection with the nature of the reactions found, furnishes a reliable

basis for making a prognosis as to recovery. A persistent lack of response on the part of the nerve after the paralysis has existed for some weeks or months, with a gradual diminution of the excitability of the muscles resulting in final loss, is unmistakable evidence of an incurable condition. If on the contrary any response, no matter how slight, can be obtained by exciting the nerve, hope of improvement may be entertained.

Injuries and diseases of the peripheral nerves, especially neuritis due to toxic and toxeamic causes, diseases of the spinal cord attacking the anterior polar cells, as anterior poliomyelitis, progressive muscular atrophy, amyo-trophic lateral sclerosis and bulbar paralysis, are among the diseases in which reaction of degeneration may be observed.

Simple atrophy and inactivity of muscles may result from a variety of causes other than interruption of nerve conductivity. Certain of these disorders are primarily muscular in their origin, as the myopathies, while others are sequences of joint disease, as articular rheumatism, or of systemic disease, as tuberculosis. These paralyses are distinguished from those having their origin in the nervous tissue by absence of the reaction of degeneration and there are times when this means for differential diagnosis is of inestimable value.

But there are cases in which the nutrition of motor nerves and muscles is altered so as to give some, but not all, of the modifications in response that are characteristic of the complete reaction of degeneration, even though paralysis may be present. All that is observed in these cases when the nerve is tested is a decrease in excitability to either direct or induced currents. This decrease may be slight or it may be so marked as to require very strong currents to elicit any response. Excitability is, however, never wholly lost nor is there any change in the quality or order of reactions. The reactions of the muscle, however, are the same as in the complete form of R. D., i. e., greatly increased excitability to the direct current and the reversed polar order. This series of changes has been found with such frequency as to justify the distinction of a *par-*

tial reaction of degeneration. Experience proves that in all cases where the symptoms belong to this form, the impairment is comparatively slight and tends to a proportionately rapid cure. Care must be taken to distinguish the partial form of reaction of degeneration from the complete form at that stage in the recovery of the nerve when it begins to respond to the direct current and the muscle is still over-excitable. Unless it is known that the electric tests showed at some previous time absence of nerve excitation, such destinction cannot always be made out. Fortunately a favorable prognosis can, in either case, be based on the fact that the nerve responds.

In some instances the qualitative modifications in the direct current reactions do not accord strictly with those which characterize either the complete or partial form of degeneration, as above deseribed. Special cases of disease show slight diversities which indicate some variation in the derangement of nutrition. This is oftentimes due to difference in degree of degeneration present in contiguous nerve fibres or muscle bundles. Such variations as these are more often seen in chronic spinal cord diseases or the milder forms of neuritis.

From what has been said it will be seen that the direct or galvanic curreut is of much value, in fact, is an indispensable aid to diagnosis when muscles and motor nerves are under investigation. By its help we are enabled

To distinguish between organic and functional disorders;

To detect the falsity of feigned diseases;

To locate lesions;

To determine the degree of motor impairment.

Prognosis and treatment often depends upon the information which it alone can furnish.

Physiological Standard for Electrical Diagnosis.

The starting point for a correct diagnosis of the state of a muscle or nerve by means of electric tests is a knowledge of the strength of current necessary to obtain reactions in normal nerves and muscles. This can be stated only in averages and in order that those averages may be valuable as a standard they should be obtained from a large number of persons according to conditions that do not vary. The only allowable variable factors are the individuals experimented on. The same points on the body should be chosen for the entrance and exit of the current; the same external resistance, exclusive of the body resistance, should exist; the same battery should be used and the same electro-motive force employed; the electrodes should be of the same size in each experiment and their coverings should be kept at the same degree of moisture. By pursuing this course a sufficiently large number of observations upon some one nerve or muscle would furnish data for the establishment of an average which would serve as a physiological standard for electric tests on that nerve or muscle. It should not be inferred from observations upon a nerve or muscle in one part of the body that like effects will follow if the test was made on some other part—for each nerve and muscle has its peculiar conditions in size, depth and expansion by which the effects of the current upon it would be modified. This laboratory has undertaken to establish a physiological standard of electric reactions upon the plan here proposed, but the observations are as yet not abundant enough for safe averages to be drawn from them. But for those of our readers who are in present need of a table of reference when making direct current tests we append the following observations on a few of the more accessible nerves of the arm The indifferent electrode (10 × 15 centimetres) made of perforated brass and covered with amadou and well moistened in one per cent. salt solution was placed on the upper portion of the sternum, while the active electrode attached to a break-circuit handle terminating in a brass ball one centimetre in diameter was wrapped

with absorbent cotton, likewise moistened. This electrode was placed as nearly as possible over each respective nerve at its crossing at the elbow joint:

CONTRACTION.	ULNAR.	MUSCULO-SPIRAL.	MEDIAN.
C. C.	1.0 ma.	1.8 ma.	0.8 ma.
A. C.	1.3 "	3.5 "	0.9 "
A. O.	2.5 "	3.7 "	1.0 "
C. O.	4.9 "	9.0 "	6.0 "

The milliamperemeter used was a *Jewell* and the number of tests made on each nerve ten. The current was allowed to remain on only long enough to take the reading.

Action of the Direct or Galvanic Current on Sensory Nerves.

The direct current as a diagnostic test for sensation has not, so far, proved of much value. There does not seem to be any selective affinity on the part of any sensory nerve terminals for this kind of excitant in preference to any other. Analgesia or hyperalgesia can be determined by means of the direct current, but the intensity of current needed to excite sensations of pain varies greatly in different persons under normal conditions. The degree of moisture or dryness of the skin is also a factor causing great variation in results. So painful does the direct current become when applied with considerable density to a limited surface of sensitive skin that it is an impracticable means for detecting slight variations in sensitiveness. The current from the secondary coil of an induction apparatus is much more suitable for making a diagnosis of cutaneous sensibility.

Numerous experiments have been made with the direct current on nerves of special sense, as the optic and auditory, with the view of determining some reactions constant enough to serve as a basis for diagnosis, but while much interesting information has been placed on record by Brenner, Erb and others, very little of practical value has so far come from it.

Choice of a Portable Battery.

The question is frequently asked by subscribers to the BULLETIN and by other physicians who wish to make use of direct or galvanic electricity for one or another purpose, "What form of portable battery should I get?" The reply to this question ought to be determined somewhat by the nature of tne work that is required to be done, for a choice might be made between batteries containing a greater or less number of cells, or cells of larger or smaller size. But in attempting an answer we will assume that the work to be done is somewhat general, electrolytic, cataphoric, catalytic, and electric diagnosis. The first requirements to be met are sufficient voltage, sufficient current, and a sufficient constancy of current for at least a half-hour treatment. While fulfilling these conditions the battery must not be too bulky, but must be so compact as to be readily transported from place to place. A choice can be made between wet and dry cells and they each have their advantages. The only wet cell at present constructed that can meet the conditions above named is that in which the liquid or electrolyte is a mixture of solutions of sulphuric acid and either bichromate of potash, bichromate of soda, or chromic acid. The advantages of a battery composed of cells with an exciting mixture of this nature lie mainly in the fact that when its capacity to generate a current deteriorates from use the parts of the cells, and the fluid as well, can be readily renewed by the owner himself and in a few minutes can be made as good as new. As such cells are usually supplied with zinc and carbon elements they are cheap as compared with some other forms, and the zinc and carbon plates, though of small size, when immersed in the fresh "bichromate" solution furnish an electro-motive force of almost two volts per cell. Fifteen or twenty such cells can be conveniently packed in small space and so made portable. The main objections to this form of battery are that the elements cannot be left in the fluid when the battery is not in use; the removal of the elements from the fluid, even when done with the greatest care, results often in

spilling some of the fluid on the enclosing box and connections which thereby become corroded and unsightly. Freezing of the fluid, fracture of the cups, and upsetting are also likely to occur, letting out the destructive fluid on carpets and furniture or carriage seat or floor. But in spite of these unpleasant possibilities, many of which can be avoided by such care and attention on the part of the owner as he would give to any good instrument, this form of portable battery will, for the large majority of operators away from the base of supplies, be found to give the greatest satisfaction.

Of dry cells suitable for portable batteries there are several forms. Some of them, such as the chloride of silver cells, can be made so small that fifty or more can be packed in very small compass.

If a "bichromate" battery of twenty cells furnishes an electro-motive force of thirty-eight or forty volts it would require almost double that number of dry cells to furnish an equal voltage. With the exception of the chloride of silver cell, thirty-five or forty dry cells would take up considerable space.

The chief advantages derived from the use of dry cells in a portable battery, arise from doing away with a corroding fluid. This insures their being much more cleanly and they require much less attention from the owner.

On open circuit the dry cells ought not to deteriorate, but it seldom happens that they do not and often they run down very rapidly when short-circuited or placed on low resistance, without giving any premonitions of the fact. The only evidence of their exhaustion is the failure to obtain a current from them, which may happen at a very inopportune moment. The necessity for sending to the manufacturer or dealer for a new supply of cells whenever such exhaustion takes place renders the use of dry cells very inconvenient to practitioners in some parts of the country.

Expense to some physicians is not so much of an item provided efficiency is secured, but the renewal of the cells of any dry cell battery now on the market amounts to a large per

cent. on the original cost, while the renewal of the elements in the "bichromate" battery is attended with trifling expense, aside from the fact that the owner is able to attend to it himself in a few minutes time.

The Jewell Cautery Transformer.

Those who have used cautery apparatus and have been subjected to the inconvenience and expense of maintaining a cautery battery, will at once appreciate the advantages of the cautery transformer, designed by Mr. Edward W. Jewell, M. E., for use on 52 or 110 volt alternating current.

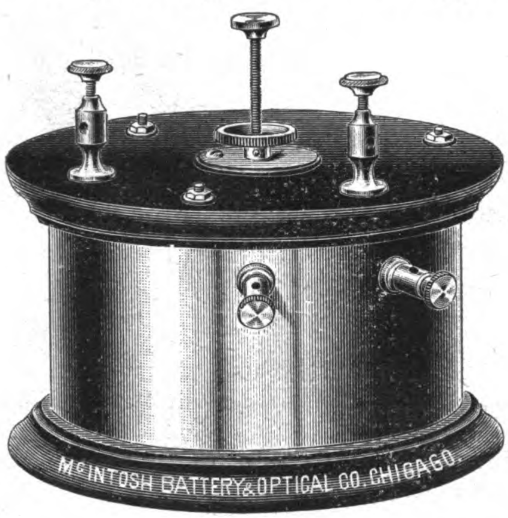


FIGURE 1.

The current from the mains enters the binding posts on the side of the instrument and, by flowing through the magnetizing coil "A" (Fig. 2) consisting of a large number of turns of fine wire, induces a rapidly reversed flow of magnetism up through the centre bundle of soft iron wires "E", across the air space in the direction of the arrows over into the laminated iron surrounding core "H" through the iron base "F", also laminated, and back into the centre core "E". It will be seen that the flow of magnetism encircles the secondary coil "B", consisting of a few turns of coarse copper strip.

The coil "B" being mounted upon the threaded rod "C", may be raised by turning the hand wheel "D". The coil will then be encircled by less and less of the magnetic flux as it is raised, and the current strength induced in the coil will be proportionately diminished.

The coils are insulated from each other, and from th ecore by the fibre insulation 'J". As the coil "B" is raised the connectors "K" fold up like the bellows of an accordion.

The current is thus under absolute control of the operator, and so perfect is the adjustment that a fraction of a turn of the milled head raises or lowers the temperature of the cautery knife a perceptible amount. The voltage of the cau-

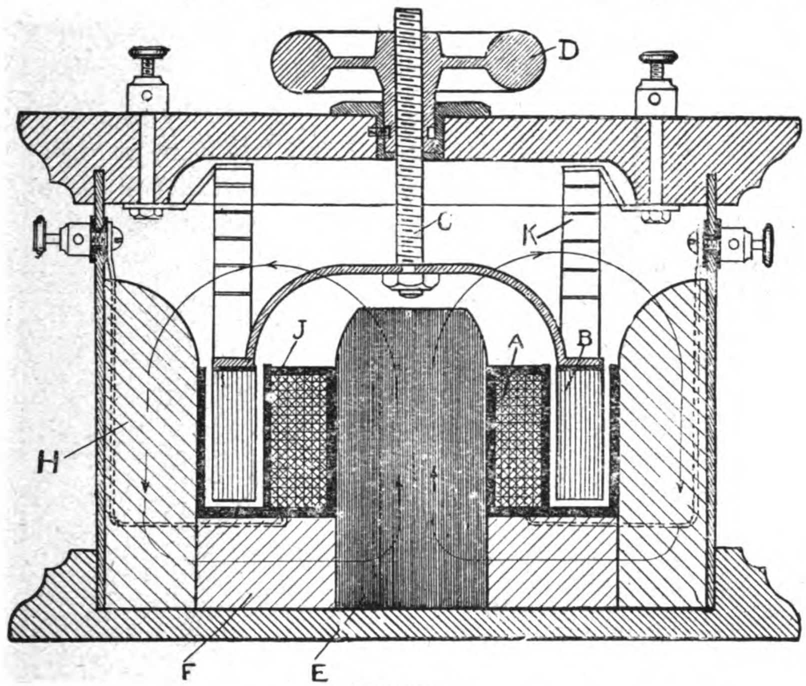


FIGURE 2.

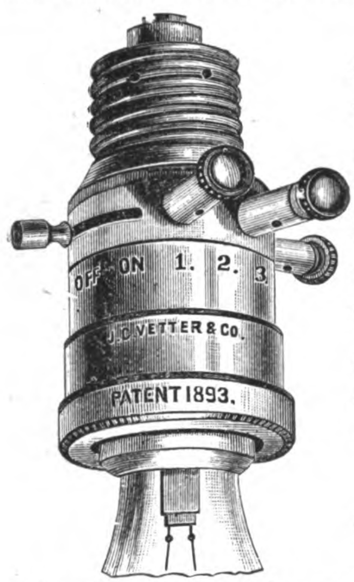
tery current thus obtained may be varied at will from 2 up to 12 volts; and may be used for lighting small lamps, or whenever a low voltage alternating current is indicated.

The transformer when heating the largest cautery knife takes from the mains about 2 amperes and delivers to the cautery knife 40 amperes. The large increase of current in passing through the transformer is offset by a corresponding diminition of voltage; a large volume of current at a low voltage being what is required in cautery work.

This instrument is manufactured by the McIntosh Battery and Optical Company.

The Vetter Current Adapter.

This is an instrument for regulating the constant current and adapting it to therapeutic uses. It resembles an ordinary incandescent lamp socket provided with a switch lever *a* and binding-posts numbered 1, 2, and 3. When connection is made with posts 1 and 2 it gives the current in series with the lamp. The quantity of this current is varied by inserting lamps of different candle power into the adapter. The maximum current for a 16 candle power lamp is ½ ampere, for a 32 candle power lamp about 1 ampere and so on. If posts 2 and 3 are used the lamp will be cut out when the switch is in the position marked "off" and the full force of the direct current is obtained. The switch lever is used only for directing the current from the binding-posts to the lamp.



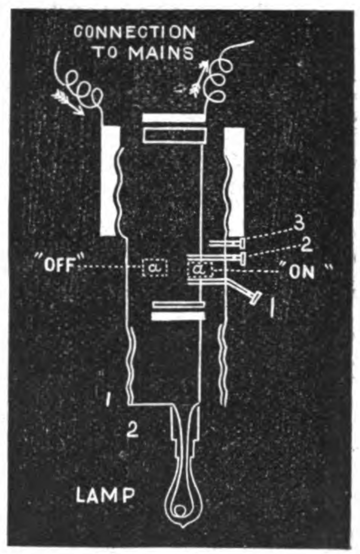
The acompanying diagram will give a clearer understanding in making the various connections with the instrument. This represents the instrument fastened in a wall socket with a lamp attached. The posts marked 1, 2, and 3 represent the connections of the corresponding binding posts while *a* and *a'* represent sections of the *a'* switch lever in the two positions "off" and "on."

If we consider first a circuit through the instrument and lamp to terminal 1, then through some instrument as an induction coil joining terminals 1 and 2, it is evident from the diagram that the current will flow through the lamp and instrument in series when the switch lever is in the position *a* marked "off" but when the switch lever is in position *a* marked "on" the current flows through the lamp and directly from terminal 1 to 2, thus cutting out the instrument but still lighting the lamp. With the lever in the "off" position, if the

circuit in the instrument joining terminals 1 and 2 be broken, the current will cease to flow. This is the case in running an induction coil, here the circuit is opened and closed in rapid succession and the variation of the current can be seen by its effect on the lamp.

When an instrument joins terminals 2 and 3 all the current drawn from the mains passes through it when the switch lever is in position *a* marked "off" but when the latter is in position *á* marked "on" a divided circuit is formed and part of the current passes through the lamp and part through the instrument.

To adapt the incandescent light current to the operations of the various translating devices requiring different strengths of current or amperage, it is only necessary to use lamps of different candle power (requiring different amperage) in the adapter and by means of conducting cords convey the current to any instrument desired. This regulation of the strength of current by means of lamps applies only to binding posts 1 and 2, and not to 2 and 3. It is therefore necessary in joining posts 2 and 3 to use a rheostat or some other modifier of current strength, unless the instrument introduced has sufficient resistance to keep the strength of current within proper limits.



The following are some of the uses to which the instrument can be put:

1. Running the induction coil.

For this purpose it is necessary to insert a 16 candle power lamp in the adapter and connect the primary of an induction coil to posts 1 and 2. So adjusted it gives about ½ ampere of current which is sufficient for most induction coils. The laboratory test was made with a 72 volt current and a

16 candle power lamp and the result was entirely satisfactory. Currents of as high electro-motive force as 500 volts, even when reduced to the proper amperage, cannot be used with the adapter in this way owing to the sparking produced at the interrupter of the induction coil.

2. For charging storage batteries.

This device furnishes a handy, clean and inexpensive method for charging storage batteries. For this purpose a 50 candle power lamp requiring $1\frac{1}{2}$ amperes of current is most suitable, the terminals of the battery are then joined to posts 1 and 2 in such a manner that the + battery terminal is joined to the + post which may be either 1 or 2 depending on the direction of the current, which must therefore be determined.

3. For the direct Galvanic current.

To obtain the direct current from the incandescent circuit by means of the current adapter, the conducting cords from posts 1 and 2 are connected to a rheostat or other device for controlling the current and to a milliampere meter. In this manner the current may be varied from 0 to 500 milliamperes, the greatest current that can flow through a 16 candle power lamp. This same method of control could be used for lighting the small incandescent lamps used for illuminating the various cavities of the body.

These are the principal claims for the instrument and it seems to fulfil them well, requiring however, in some cases the use of other instruments for properly controlling the current.

The following are probably the chief limitations of the instrument.

1. It can be used only on a direct dynamo circuit of low voltage, as the Edison of 110 volts.

2. The method of regulating the strength of current by introducing lamps of varying candle power is a very slow and cumbersome one and incapable of delicate variations without the assistance of other controllers

Electric Treatment of Chronic Rheumatism.

[CONTINUED FROM NO. I.]

We will now consider the mixed electric treatment, that is, a general electric treatment employed concurrently with a local. The electric treatment of chronic rheumatism will be of long duration. It requires much regularity on the part of the patient and much patience on the part of the doctor. The results of the treatment are usually slow in manifesting themselves clearly, and the improvement progresses little by little. We desire to indicate this probable long duration so that neither physician nor patient will be disappointed in their expectation of the awaited happy result which, we repeat, will appear very slowly but surely. The very nature of the disease and the whole of its lesions easily explain the slowness of treatment. Each sitting should be divided into two parts: In the first local treatment should be given, in the second the general. At the beginning of treatment and for some time the sittings are to be daily if possible. Later they should be every two days and finally could be every three days. But the sittings should never be less than two a week as long as the patient is not improved to the point when he may be considered cured. Those cured, however, are not to completely abandon the treatment. They should increase the time between sittings more and more and stop them entirely only when the cure remains complete and entire. We would advise rheumatic patients, whether benefited or cured by electricity, to submit themselves every three or four months to a course of general treatment for three weeks (two to three sittings a week). Rheumatic patients ought not to forget that they are always in the power of the disease, and that it is wise for them to employ a treatment which, as the general electric treatment, can enable them to prevent the baneful morbid manifestations of their disorder.

A word now of the total length of each electric sitting. It ought necessarily to be pretty long because of the division

of the sitting into two parts. Nevertheless the special length of the general treatment can be pretty well settled in advance. It varies from 20–30 minutes if one uses the static treatment, and from 15–20 minutes if one uses the alternating current.

The special length, on the contrary, of the local treatment varies within large limits. It is dependent upon the number and importance of the morbid phenomena submitted to treatment. For each of these phenomena in particular the treatment will be that indicated above. As to our individual preference regarding the various methods, we would recommend the employment of the static current more especially for the general treatment, and of the continuous, for the local.

Notes.

The American Electro-Therapeutic Association.

The annual meeting of the American Electro-Therapeutic Association will be held in Toronto, Canada, during the first week in September. Any persons wishing to obtain information as to hotel accommodations, space for exhibits of apparatus etc., can do so by addressing Dr. C. R. Dickson, of 159 Bloor St., or Dr. Holford Walker, 56 Isabella St., Toronto, Canada.

A Journal for Doctors and Dentists,

It is with pleasure that we note the appearance of *The Electrical Journal* which made its advent in Chicago, on June 1st. This Journal is of special interest to members of the medical profession since it is the avowed purpose of the managers to give systematic attention in its columns to the applications of electricity to the requirements of medicine and surgery. This is the only electrical periodical published in this country which has attempted, in any thing more than a desultory way, to meet the needs of the members of the medical and dental professions and we hope many will avail themselves of the help which it offers them in making electricity useful in their therapeutic work.

VOLUME II. OCTOBER, 1895. NUMBER 4.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN.

Published Quarterly by The Inland Press, Ann Arbor, Mich.
Subscription Price, One Dollar a Year.

Direct or Galvanic Current for Cautery and Light.

The use of electricity for heating a wire or for lighting a lamp is not a direct therapeutic application of it, since in the one case it is heat that is the therapeutic agent and in the other, light, used only as an accessory means to diagnosis or treatment. But electricity serves as a convenient source from which to obtain the heat or light, and thus renders possible efficient methods of treatment not otherwise obtainable. The galvano or electro-cautery has the advantage over the actual or thermo-cautery in being more readily heated and kept heated. It can also be minute in size when it is so desired, and can be conveyed to the part to be cauterized cold, as in nasal fossa or larynx, and then, when in place, heated to the degree required for doing its work, and again cooled before withdrawal. The electric lamp can be made of such size and so mounted as to be conveyed into and so illuminate any of the accessible cavities of the body. It devel-

ops but little heat, gives a superior white light and can be held in any position; all of which advantages render it superior to any other method of illumination, where this is an aid to diagnosis or treatment.

The direct or galvanic current, when employed for heating cauteries or lighting exploring lamps, can be obtained from primary batteries, secondary or storage batteries, or from dynamos.

Hitherto, when considering the therapeutic uses proper of the direct or galvanic current, such as electrolysis, cataphoresis, catalysis, etc., we have dealt with the resistances of the tissues of the body, which are uniformly high, and with currents of small quantity, seldom more than 20–30 ma., and never more than 300 ma. When we attempt to use the current for heating a cautery or for lighting small lamps, these conditions as to resistance and quantity of current are greatly modified, which necessitates a corresponding modification in the appliances used to furnish and regulate the current. The prime object in using an electric current for cautery purposes is to generate heat to keep the cautery blade or loop at the required degree of incandescence. The amount of current necessary to do this varies according to the size of the cautery burner used and the conditions of the part on which it is used. An average of from 15 to 20 amperes of current is needed for an efficient electro-cautery apparatus, and, since in the course of a treatment by means of the electro-cautery the amount of current may need to be quickly increased or decreased, a rheostat or other means for readily modifying the strength of current is indispensable.

Nature of Apparatus.—The batteries we have hitherto considered for sending currents through the tissues of the body are not adapted for this cautery work, since they are not capable of generating currents of such large quantity. One-half an ampere (500 milliamperes) would be a very good output for a battery designed for tissue electrolysis or electric diagnosis, but such a battery, though composed of many cells, would be of no use in heating a cautery. Neither would the controllers or rheostats that are ordinarily used to modify the

direct currents used for therapeutic purposes serve to control cautery currents; for if fluids entered into the construction of the rheostat, the great quantity of current would quickly evaporate them by heat, and if composed of wire it would be melted. If, therefore, a primary battery is to be used for heating a cautery, it must be of peculiar construction and have a rheostat attached to it that is adapted to the quantity of current the battery is capable of producing.

The external resistance in a cautery circuit is very small. It is intended, also, that the cautery burner should be the most resisting point in the circuit, since it is here that the heat must be developed. All other parts composing the external circuit, the cords, handle, connections, etc., are therefore made of large size, so that they may offer but little or no resistance. This entire resistance, including the cautery burner, seldom exceeds one-tenth of an ohm. With so small external resistance, the internal or battery resistance should likewise be small, (since a battery does its work most perfectly and with the greatest economy when internal and external resistance are as nearly equal as possible.) 9

In order to diminish internal resistance in a battery, the plates should be large and near together and every precaution should be taken to prevent polarization. If cells of large size are inconvenient and make the battery too cumbersome, cells of smaller size but more of them can be used, provided the elements are coupled in multiple arc and not in series as is the method of joining them when greater resistances are to be overcome. By using a bichromate of potash cell with large zinc and carbon plates near together, the internal resistance can be brought down to at least 0.15 of an ohm. One such cell with an electro-motive force of two volts would furnish a current, therefore, of eight amperes.

$$C = \frac{E}{r+R} \qquad C = \frac{2}{0.15+0.1} = \frac{2}{0.25} = 8 \text{ amperes.}$$

By increasing the number of cells and coupling them in multiple, the internal resistance is reduced proportionately and the amount of current is increased. In all primary batteries generating a large current, polarization takes place readily,

and this by increasing the internal resistance quickly diminishes the current. The current reduced in this way soon fails to heat the cautery, and such a mishap must be prevented. This can be done in one of two ways. Either by keeping the plates in the fluids moving so as to wash off the gases and other *ions* which tend to accumulate on the plates; or, secondly, by having at the outstart a current capacity far in excess of the amount required to heat the cautery, but with an external resistance in the circuit in the form of a rheostat to control and regulate the current to the required amount. This latter is by far the more convenient method.

Primary Cautery Battery.—If a primary battery is to be used to obtain a current for a cautery, its construction must be such as to conform to the conditions above indicated. It must have but small internal resistance and be capable of furnishing a large amount of current. Experience has shown cautery batteries made of zinc and platinum or zinc and carbon elements with bichromate of potash or soda, or chromic acid solution to be the most efficient. Such a battery composed of from two to six cells, with plates of large size, can be coupled in "series" or "parallel" according to the resistance of the cautery circuit. A higher electro-motive force is required to maintain a long loop of wire at the proper degree of heat than is needed when the burner is short and thick. A cautery battery of this kind has all the disadvantages that usually attend this method of obtaining a direct or galvanic current; but if the operator will give to it the necessary care and attention he will have an independent source of supply of current ready for use at any time. Such a battery should have in the cautery circuit a rheostat having a few ohms resistance. The rheostat should permit prompt change of resistance, and all resistance should be in the circuit at the moment the burner is first attached and the battery current thrown on, then the resistance can be thrown off gradually until the burner is brought to the required degree of incandescence. This amount of heat can be easily maintained by varying the resistance of the rheostat as long as the battery current is flowing or the operation continues.

The conditions attending the maintenance of a current such as will keep an incandescent lamp at the proper degree of brilliancy differ somewhat from those required for cautery work. The carbon filament of the lamp may be compared to the burner of the cautery. It must be the point of greatest resistance in the circuit. The resistance of different lamps varies from 3 to 200 ohms, depending upon the length and thickness of the filament. The resistance of the small incandescent lamp commonly used in illuminating the cavities of the body varies from 6 to 30 ohms. When the carbon filament becomes heated the resistance is slightly decreased, but the difference is not so great as to be taken into account, and it is not necessary, therefore, as in case of the cautery, to provide for a great variation in the amount of current. The current needed to raise these lamps to a white heat varies from .3 to 1.6 amperes according to the resistance of the lamp. It will be seen, therefore, if a primary battery is to be depended upon to furnish the current its capacity and arrangement should be determined by the resistance of the lamp and the strength of current necessary to keep it properly lighted. The least resistance given by a lamp is far in excess of the resistance of any cautery burner. A higher electro-motive force is required, therefore, for lighting lamps than for heating cauteries.

A primary battery can be made to serve equally well for cautery work and for lighting lamps if it is so constructed as to permit of changing the manner of coupling the cells so as to vary the electro-motive force and quantity of current to meet the conditions in external resistance.

Even though a lamp resistance varies but little, the internal resistance in a primary battery soon changes when the battery is at work. A rheostat or controller for maintaining the current in the lamp circuit at the proper amount is quite as necessary an attachment to a battery used for lighting lamps as in one for heating cauteries.

Secondary or Storage Batteries.—A well constructed storage battery or accumulator, freshly charged, is an ideal source from which to derive a current for cautery or for light-

ing lamps for illuminating the cavities of the body. Storage batteries of several patterns are now manufactured to meet the needs of physicians. They are cleanly, portable, constant in electro-motive force (2 volts per cell) and furnish a current for double the ampere hours that a bichromate battery of equal size will do. There are certain drawbacks, however, that attend their use, which prevent many from depending upon them. They require charging quite frequently (once in two or three months), either from a direct current dynamo of suitable voltage or from a series (two or more) of gravity cells. This recharging is necessary to keep them in good condition, whether they are in use or not. Much care is required both in charging and discharging the plates, for they can be easily damaged, and this result frequently happens either from accident or from carelessness on the part of the operator or his assistant. There is no way by which the amount of charge remaining in the battery at any time can be predetermined, so that the current may fail the operator at a critical moment. Every storage battery used for either cautery or lamp work should be furnished with a rheostat for controlling the battery output and graduating the current so as to accord with the resistance of the cautery burner or lamp filament. When the discharge is short-circuited, that is, opposed by insufficient resistance, not only is there a waste of current but it does injury to the plates, and an uncontrolled current is liable to melt the cautery burner or loop or burn out the lamp filament.

Dynamo Circuits.—These are often a convenient source of electric energy for both cautery and lamp uses, and when the supply can be obtained from this source all the annoyances that arise in the use of primary or secondary batteries are done away with. The alternating dynamo current serves quite as well if not better than the direct for heating cauteries and lighting exploring lamps, and as there is much to be said upon this subject it will be treated of in a separate article.

Rheostats.

The question as to what form of rheostat is required by a physician practicing electro-therapeutics can be answered only by knowing the nature of the current he is intending to use and for what purposes he uses it. A rheostat to be used for modifying and controlling the large currents employed for cautery work must have a very different structure and current carrying capacity from one that is to be used to modify the weaker currents that traverse the body. The former needs but small resistance, but large capacity for carrying current without heating; the latter must have a wide range of resistance and requires but little current carrying capacity.

In treatments where the current traverses the body, it is seldom that more than 150 ma. of current is required. If the source of this current is a battery of cells in series giving an electro-motive force of 50 volts, the combined resistance in the body and in the rheostat must not exceed 333 ohms if the current is to reach 150 ma. But if the current needed is but 5 ma. and the same battery is used, then the combined resistance of body and rheostat must be as much as 10,000 ohms. This is a very wide range of resistance, most of which must be provided for in the rheostat, since the body resistance is too uncertain a quantity to depend upon. The current in these cases is, at the greatest, so small that such a rheostat could be made of very fine resistance wire, as No. 36 or No. 40 German silver. German silver or other resistance wire is needed where extreme accuracy is required and it is important to know exactly how much resistance is at any one moment added to or withdrawn from the circuit. Its resistance is constant, and a long coil of such wire tapped at known intervals and marked with the amount of resistance each segment gives makes the best form of rheostat. But a wire rheostat is expensive, and since the thing of chief importance in this kind of electro-therapeutic work is to know the amount of current, any material in a rheostat will meet the need that serves to keep the

current at the required amount and can furnish a sufficient range of resistance to provide for a change, with a fairly uniform gradation, in the amount of current when it is desired. Rheostats composed of water in a suitable receptacle will do this, and many good water rheostats are in use. But if any metal enters into the construction of a water rheostat it is soon corroded, and the corrosion takes place more quickly when the electrolytic action of the current is added. The water evaporates and needs to be replenished, and the receptacles for the water are usually made of glass and are often broken.

THE JEWELL RHEOSTAT.
(Manufactured by McIntosh Bat. & Opt. Co.)

The Massey rheostat, composed of a circular piece of marble over which moves a radial arm, with a contact at the outer end of the arm which brushes a thin layer of graphite, makes a most durable aud serviceable instrument for the electro-therapeutist and is much in favor. The graphite, which is the resisting substance, is rubbed off by use but is readily renewed by means of a carpenter's pencil. A rheostat of similar construction is here figured. It is composed of a block of slate in which grooves are cut. These grooves are so constructed with reference to the moving arm as to make a continuous line equal to the sum of the lengths of the grooves. The grooves are filled with a composition which is highly resisting. This dries in the grooves and is then leveled to the surface of

the slate. This rheostat possesses all the advantages of the Massey and does not require the replenishing of resisting substance. A test of its resistance was made in this laboratory, which shows the full amount is 10,000 ohms. The resisting surface of the rheostat was marked off from the point of full resistance to the point of least resistance at five equal intervals and the resistance tested at each point. Four-fifths of the resistance was 4,444 ohms; three-fifths, 2,350 ohms; two-fifths, 1,333 ohms; one-fifth, 888 ohms. The point of least resistance registered 3 ohms. It will be seen from this that the range of resistance in this instrument is wide enough for all practical purposes, giving a maximum and minimum that render it suitable for controlling all currents of comparatively low voltage that are used on body circuits. But it becomes a matter of greater difficulty to control by means of a simple and inexpensive rheostat a dynamo current of such a voltage as has been found serviceable in electro-therapeutics—currents at a pressure of from 100 to 500 volts. Should the rheostat here figured be put in the 100-volt circuit, all of the resistance which it furnishes (10,000 ohms) would only reduce the current to 10 ma., and oftentimes this is more current than is required, and it would need an increase of the resistance to 20,000 ohms, with all of it in circuit, in order to reduce the current to even 5 ma. With the 500-volt current such a rheostat would need to be still further modified if it is desired to use currents ranging from 5 to 20 ma., for to reduce this current to 10 ma. would require a resistance of 50,000 ohms, and to reduce it to 5 ma. would require 100,000 ohms. A rheostat of this type in order to have this range of capacity would need to be very bulky and cumbersome, and there are much simpler and more efficient instruments for modifying these dynamo currents of high electro-motive force and bringing them within the limits required by electro-therapy. (See Vol. I, No. 2, p. 24.)

For cautery work and lighting lamps the rheostat has to deal with very different conditions. A current of from one-half to one and one-half amperes is required for lighting lamps, and for a full line of cautery instruments a current of

from 1 to 30 amperes is needed. The resistance to be overcome is, in both cautery burners and lamps, very small, compared with the resistances in the body. A primary battery with cells arranged in series would not furnish this amount of current because of the large amount of internal resistance in the battery circuit, and for other reasons stated in the leading article of this number of the BULLETIN. The kind of battery that would furnish the necessary current is also there described.

Should an attempt be made by means of a rheostat to get from a dynamo current of 100 volts a current suitable for cautery work, the rheostat, if arranged to modify the current by introducing more or less resistance directly into the circuit with the cautery burner, need have no more than 100 ohms resistance in order to reduce the current to as little as one ampere, and to do the same with the 500-volt circuit the rheostat need contain but 500 ohms resistance. But a wire rheostat that would give even this amount of resistance and at the same time be made of wire large enough to safely carry the current required by most cauteries (5 to 10 amperes) would need to be made of such large wire and would take so much of it as to be too unwieldly and expensive to be practicable. No such difficulty would attend the construction of a rheostat for lighting lamps from these dynamo currents, however, for the amount of current needed is much less. Rheostats such as the Massey and the Jewell have too much resistance for doing this class of work, neither would the material of which they are composed carry such large currents. Shunt rheostats or controllers such as the K. A. P. (Vol. 1, No. 4, pp. 54) can be constructed for adapting the direct dynamo currents of high voltage to cautery work, but the expenditure of energy is enormous in proportion to the need, and it is, in consequence, an expensive method. Alternating dynamo currents even of high voltage can be readily modified for both cautery and lamp work by the use of suitable transformers, where the primary and secondary windings are adjustable in their relation to each other. Several excellent instruments of this class are now on the market. (See Nol. II., No. 3, p. 106, of this BULLETIN.)

Dynamo Currents.

SUCH AS CAN BE USED BY THE PHYSICIAN AND SURGEON FOR HEATING CAUTERIES OR LIGHTING EXPLORING LAMPS.

Any dynamo current, whether direct or alternating, that is at present employed for lighting an incandescent lamp system can be made to do duty in heating a cautery or lighting a lamp for therapeutic uses. But, while this is practicable it is not in all cases equally advantageous, at least with the present appliances for controlling such currents for these purposes. The Edison incandescent lighting system is supplied with a dynamo which ordinarily maintains a pressure of near 100 volts. The lamps in this system each require one-half ampere of current. A cautery needing from 15 to 25 amperes of current to maintain it at the proper degree of heat would while in use on this circuit consume a current sufficient to light 30 to 60 lamps. This amount of energy, therefore, would need to be reserved in such a system for this instrument. Few owners of small lighting plants would be willing to hold in reserve so large a proportion of their available capacity, since the cautery, though a very useful tool at certain times, is not likely to be kept in such constant use as to justify holding so much energy in readiness for it, and if the physician was required to pay for such reserve he would find it a very expensive luxury. The K. A. P. rheostat, which was fully described in Vol. I, No. 4, of this BULLETIN, was designed for use on this circuit and has been found by many physicians to be a very satisfactory working instrument. The resistance of this rheostat never exceeds 4 ohms. When the cautery burner is in shunt circuit with the main circuit the resistance is still less, therefore $C = \frac{100}{4-} = 25+$ amperes. The office where such a rheostat is to be used must be specially wired

for the purpose and the fuse must be of such size as to insure the passage of a current of 25 amperes. But there are direct current dynamo circuits other than those employed in incandescent lighting that can be utilized by the physician, surgeon and dentist. Many of the street car circuits are supplied with direct current dynamos. These commonly maintain an electro-motive force of 500 volts. There are direct current dynamos also used as power generators which distribute the current over a limited area at a pressure of 500 volts.

The main practical difficulty in using direct currents of this high voltage for heating cauteries and lighting lamps is in getting a rheostat to suitably modify the current that is not too cumbersome. The resistance of the K. A. P. rheostat is much too little to permit it to be used on a current of such high voltage. A shunt rheostat, with a resistance of 10 ohms in the main circuit, would give a current of 50 amperes, and it would require a wire of large size to safely carry a current of this capacity. Large sized wire offers but little resistance, and the quantity of wire that would be required to give even 10 ohms resistance would make a very unwieldly appliance. Water rheostats might be made that would serve the purpose better and be of less bulk, but there are none yet on the market for controlling cautery currents. The motor-dynamo, which is an invention of recent date, will, no doubt, eventually be brought into requisition for adapting these direct dynamo currents to the needs of therapeutic work. These devices can be so wound as to deliver in the physician's office from street mains any strength of current he may require, from half an ampere to 50 amperes. The motor-dynamo for cautery work would need to be differently constructed, however, from one that would be adapted for other kinds of constant current service, and in each case a further modifier of the current, as a controller, would still be needed.

Incandescent lighting of houses and offices is now very generally done by means of alternating current dynamos. While the electro-motive force of the current on the main circuit of this system is often as high as 1,000 or 1,500 volts, it is transformed before entering the house or office circuit to

50 or 100 volts. A similar device, in principle, to that which reduces the electro-motive force before it enters the building can again be employed by the physician for still further modifying the electric energy. He can have a transformer or converter attached to this circuit in his office that will diminish the electro-motive force and increase the current, or another form that will decrease the current and increase the electro-motive force. A transformer for cautery or lamp lighting purposes can be easily constructed for use on this kind of dynamo circuit. It can be arranged like the Dubois-Raymond coil, one coil of the transformer made to slide over the other, or as the Jewell Cautery Transformer, which was figured and described in the last number of this BULLETIN, where a coil of large sized wire is made to move up and down in a strong magnetic field. This is a neat and very efficient means for heating cauteries or lighting exploring lamps and is available wherever the alternating dynamo current is accessible. The alternating current has more direct therapeutic uses than these, but of that we will treat in a future number of the BULLETIN.

A Word of Explanation.

This issue of the BULLETIN has been delayed two months because of the illness of the Director of the Laboratory of Electro-Therapeutics.

With this number the discussions of direct or galvanic current action in therapeutics, and descriptions of appliances for generating and using this form of current, will, for the most part, cease. The future numbers will be devoted mainly to the consideration of induced currents and static electricity.

Fuse Wire.

The electro-therapeutist has had little occasion until recently to seek information regarding the properties and peculiarities of fuses and fuse wire. But now instruments are coming into very general use designed to adapt to therapeutic work certain of the dynamo currents that are employed for industrial purposes. Some of these instruments convey the current in a modified form direct from the dynamo to the patient. Others provide a shunt circuit into which the patient is introduced. But in either case every precaution should be taken to render it wholly impossible for the patient to receive a current in excess of the amount intended to be given in the treatment. One means adopted to protect both the patient and the rheostat or controller is to cause the current to pass through a fuse wire so placed in the circuit that it will cut off the connection between the controller and the dynamo by burning out whenever the amount of current is greater than desired. There is no necessity in any treatment for subjecting a patient to more than half an ampere of current, and very rarely, indeed, is anything like this amount used if the current is to be passed through the tissues of the patient. From 10 to 30 milliamperes is the range commonly employed in direct or galvanic currents, and a much less amount than this in induced, alternating or static currents. But half an ampere of current is not dangerous to the human organism, nor would it be especially harmful if not too long applied. An instrument such as a rheostat or controller used for adapting a dynamo current to therapeutic uses can be used with perfect safety if it is guarded by a half-ampere fuse between it and the main circuit. By a half-ampere fuse, however, is meant one that will surely and promptly burn out the instant the current reaches half an ampere. It is well known by electrical experts that fuse wire is a very uncertain article. Very commonly it will carry twice or thrice the amount of current that it is said to carry. Some specimens of fuse wire have

recently been received at this laboratory purporting to be half-ampere fuse wires, which upon test were found to carry 2.2 amperes. One piece labeled for one ampere required 3.8 amperes to melt it, and another 4.5 amperes. A specimen of two-ampere wire carried 8.6 amperes and then had not reached the fusing point. It must not be surmised from this that there need be any such uncertainty in regard to the action of the fuse wires which are used to protect these controllers from currents dangerous to the patient. Fuses can be made and are made that will not allow the current to exceed half an ampere, and they can be adapted to even a much less amount of current than this if there is need for it. So far fuses have done service in circuits doing illuminating or industrial work where the variation of an ampere or two in the amount of current would do no harm. But where the delicate structures of the human body are to be made a part of the circuit for a current, all possibility for such variation must be set aside and absolute certainty of safety must take its place. The makers of the better class of rheostats and controllers for physicians' use can be relied upon to take the necessary steps to provide in this matter against accident from excess of current.

The rating and behavior of fuse wires was one of the subjects under discussion at the October meeting of the American Institute of Electrical Engineers. The topic was introduced by a paper prepared by Prof. W. M. Stein and others giving an account of experiments upon fuse wire recently conducted at Armour Institute, Chicago. The following conclusions, drawn from the results of those experiments, were presented by the authors of the paper: 1. Covered fuses are more sensitive than open ones. 2. Fuse wire should be rated for its carrying capacity for the ordinary lengths employed. 3. When fusing a circuit the distance between the terminals should be considered. 4. On important circuits, fuses should be frequently renewed. 5. The inertia of a fuse for high currents must be considered when protecting special devices. 6. Fuses should be operated under normal conditions to insure certainty of results. 7. Fuses up to 5 amperes should be at

least one and one-half inches long, one-half inch to be added for each increment of 5 amperes capacity. 8. Round fuse wire should not be employed in excess of 30 amperes capacity; for higher currents, flat ribbons exceeding 4 inches in length should be employed.

In the discussion that followed, Dr. Emery, of New York, expressed the opinion that copper was much the best material for fuse wire. He also suggested a convenient rule of thumb for rating copper wire as fuse wire, which is to divide the carrying capacity by two for every third size of wire going up the scale, starting with some number the value of which is known.

Notes.

Uniformity in Connectors.

At the Toronto meeting of the American Electro-therapeutic Association in September, the Committee on Electrodes through the chairman, Dr. Charles R. Dickson, suggested the adoption by the Association of standard connectors such as conducting cord tips and the electrode and binding post orifices. The suggestion was received favorably by the members present and was also approved by all the representatives of manufacturers of electro-therapeutic appliances. The cord tip which has thus received the sanction of this Association is the adjustable tip long manufactured by the McIntosh Company, which, aside from forming a strong terminal to the conducting cords, permits the operator to readily adjust a new cord to it when the old one is worn out. If such a tip is universally adopted and all electrodes are supplied with a slot-spring opening to receive it instead of a hole with a binding-screw, many petty annoyances and obstructions to successful electro-therapeutic work will be done away with and both physicians and manufacturers will be gainers by the change.

VOLUME III. JANUARY, 1896. NUMBER 1.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN.

Published Quarterly by The Inland Press, Ann Arbor, Mich.
Subscription Price, One Dollar a Year.

The Physician's Induction Coil.

To rightly understand the therapeutic capacities of the faradic battery or physician's induction coil it is necessary to start with a clear conception of the mechanism by which the various currents derived from this apparatus are produced.

The analysis of one of the simpler forms of induction coil, such as is commonly employed by physicians will best serve this purpose as it contains all the essential elements entering into this form of apparatus. The more elaborately constructed coils are but attempts to perfect the working of one or more of the parts of which these simpler or cheaper coils are composed. The induction coil apparatus used for therapeutic purposes must have—

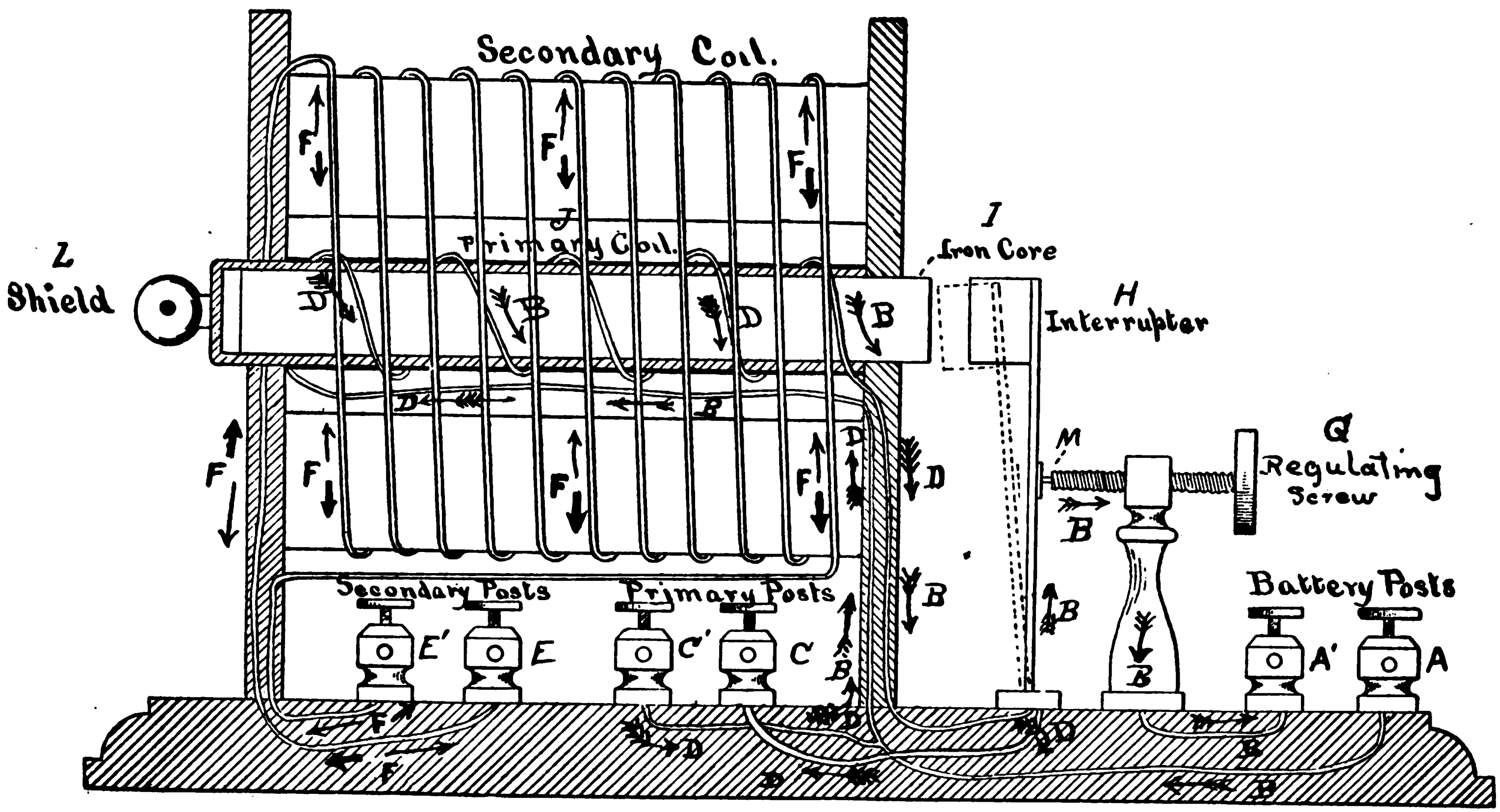
A primary battery, or other original source of current,
A primary coil,
A temporary magnet,
An interrupter, or circuit-breaking device,
A secondary coil,

Some means for varying the amount of current induced in either coil.

We will give separate consideration to each of these parts.

The Primary Battery.—In the ordinary portable faradic battery one or two wet or dry cells furnish the current which excites the induced currents in the coils. The number and electro-motive force of these cells must be proportionate to the resistance to be met with in the coil circuits. When wet cells are used they are commonly either the bichromate or ammonium chloride cells. The electro-motive force of the former (1.9) is about one-fourth higher than the latter (1.4), neither do they polarize so quickly and therefore maintain a more constant current. The dry cells are more convenient because of being dry, but they cannot be renewed by the operator but must, when exhausted, be replaced by new ones. The composition entering into the various dry cells is a trade secret, but those of larger size usually have zinc and carbon elements with a paste containing ammonium chloride as an excitant. The chloride of silver dry cell is the most convenient because of its small size—but its electro-motive force (.9) is less than that of other forms of dry cells. It requires from two to three volts pressure to properly energize the ordinary induction coil apparatus, and a dynamo current can be used to furnish this current quite as well as a primary battery. With coils of greater resistance more electro-motive force is needed in the circuit from which the primary energy is obtained, and in case primary battery cells are used to supply this current the number must be sufficient to meet the requirements of increased resistance. So it happens that in certain forms of induction apparatus recently put upon the market, in which the secondary coil contains a great many turns of very fine wire, four or more primary battery cells are needed to properly energize the coils.

The Primary Coil.—The main purpose of the primary coil is to furnish a path for the battery current and to interrupt and transform that current in such a manner as to create induced currents in a secondary coil which is either wholly or



Working Diagram - Physicians · Induction Coil

but partly within its field of influence. To accomplish this purpose the primary coil need be made of but few turns of a comparatively coarse wire; the main object being to offer but little resistance to the primary battery circuit, Our laboratory experimental induction coils contain three turns of number 19 wire (about 50 feet) in the primary coil, the outside diameter of the coil being 2 centimeters and its length 10 centimeters. There is, as we shall presently see, a current possessing peculiar physical properties induced in this primary coil, which is utilized for therapeutic purposes and called the *primary current.* For the purpose of giving a different quality to this primary current some manufacturers have increased the number of turns of the primary coil and used wire of different sizes. The battery current which traverses the primary coil has for a part of its course a vibrator spring (B′) and a set screw and post (B″) which form very essential elements in the action of the induction coil apparatus as will be seen later.

A Temporary Magnet.—A soft iron bar or a bundle of soft iron wires capable of being readily magnetized by the passage of the battery current along the primary coil and again promptly losing its magnetism as this battery current is interrupted, is the part of the induction coil apparatus upon which its action chiefly depends.

The main purpose of the temporary magnet is to break the battery circuit and so interrupt the flow of current from the battery through the primary coil. This the temporary magnet does the instant it becomes magnetized through the influence of the current passing in the primary coil which is wound about it. By its magnetic force it attracts the iron head on the vibrator spring or interrupter (B′) and draws away the spring from the point of the adjusting screw (G) and so leaves a gap (M) in the battery circuit. This stops the flow of the battery current in the primary coil. The soft iron core then loses its magnetism and releases the head of the vibrator spring which flies back and is again in contact with the point of the adjusting screw. A second advantage gained by the temporary magnet, if placed, as it is in many of the simple

forms of induction apparatus within the turns of the primary coil, is an augmenting of the inductive effect on the coils by reason of the magnetic lines of force emanating from the magnet and cutting the turns of wire in the primary and secondary coils. In some of the Dubois-Reymond forms of induction coil the temporary magnet is used only to interrupt the circuit of the battery current and is placed at a distance from the primary and secondary coils and this augmenting inducing action upon them is lost.

A Circuit-breaker or Interrupter.—The current that flows from the battery through the primary coil must be broken or interrupted at intervals, since it is by the change of potential in the circuit that is thus produced that the induced currents in the coils are created. The range of frequency of such interruptions is determined by the kind of device that is used for producing them. In the ordinary coils the interruptions are effected by a spring at the extremity of which is an iron head (H). This bit of iron is alternately attracted to and released from the temporary magnet. The rapidity with which interruptions can be made by this mechanism varies greatly in different instruments. It depends upon the strength of the magnetic flux, the readiness with which the magnet takes on and gives up its magnetism; the length of the spring and its elasticity. Seldom do any two instruments of the same pattern agree in all of these particulars. The maximum of interruptions that can be brought about in our ordinary laboratory coils averages 60 per second, and these are a fair sample of the induction coils in general use. By greater attention to details in the construction of this and other parts of the induction coil, as in the use of longer and more nicely adjustable springs, and the use of a quality of iron in the temporary magnet that will insure the greatest promptness in response to the inductive influence, the rapidity of interruptions by this method can be considerably increased, but we have yet failed to find an instrument with a spring vibrator in which the number of interruptions can be made to reach 200 per second. The number of interruptions in an induction coil current is one of

the important elements in producing physiological and therapeutic effects, since the greater their frequency the more the sharp and irritating quality of the current is reduced, and the more soothing it is in its influence. Numerous attempts have been made to secure more rapid and uniform interruptions by other arrangements than that of the spring vibrator, but so far the devices have been either too complex or expensive as compared with the additional advantages they offer to create much demand for them. The Englemann segmented rotary interrupter, run by an electric motor, is capable of greatly increasing the number of interruptions and with perfect uniformity, but its cost places it beyond the reach of the majority of those using induction coils.

The Secondary Coil.—The secondary coil is the induction coil proper, and the current derived from it can be caused to vary considerably in strength and quality at the will of the operator. This coil is always made of finer wire than that used in the primary coil. It usually has a much greater number of turns also and the length of the wire is, of course, proportionately increased. In our laboratory experimental coils the secondary is wound with number 31 wire and has 3 layers, the length of wire used being about 180 feet, the resistance of which is about 35 ohms. Most secondary coils for physicians' use are now made of still finer wire. Number 36 is preferred by many, and the number of layers is as many as eight or ten or even more. The finer the wire the greater the number of turns made in each layer, and as each additional turn of wire adds one to the frequency with which the lines of magnetic force, emanating from the primary coil and the temporary magnet, cut the secondary coil, and so increase the electro-motive force of the secondary coil current, a great number of turns in the secondary coil is by some thought desirable. But there is a limit to the advantages to be gained by lengthening the wire and increasing the number of turns in the secondary coil. The resistance of the amount of wire used and of the self induction created in the coil may prove too much for the primary battery current to

overcome and the resulting secondary induced current will be very feeble. As much of the efficiency of the faradic or induction coil apparatus depends upon the nature of the secondary coil current aud a different quality is required in this current for different therapeutic purposes, some manufacturers provide several secondary coils with different sizes and turns of wire. Others make a continuous winding of the one size of wire but make this of considerable length, and then tap the wire at intervals so that the current from all or only a part of the coil can be used as desired. The nature of this secondary current as compared with the primary induced current will be dealt with in a separate article in this number of *The Bulletin.*

Current Regulation.—Every induction coil apparatus is provided with some means for increasing or decreasing the strength of the currents derived from it. This is done by modifying the strength of the magnetic field that induces currents in the coils—one of two ways is used to do this. The coils are arranged, in the one case, to move one over the other as in the Dubois-Reymond type of coil, the form usually employed by physiologists for their experimental work, and which produces very fine and uniform gradations in the amount of current, or a metal shield of brass is made to slip over the temporary magnet placed in the axis of the coils which shield, when in place, attracts to itself the lines of magnetic force emanating from the magnet and prevents them from cutting across the turns of this coil. As the shield is removed the lines of magnetic force are released and induce currents in the coils in proportion to the extent to which the magnet is uncovered. A crude method of measuring the strength of induction coil currents is to attach an inch or meter scale to the apparatus so as to measure the position of this shield at any moment or the extent to which one coil covers the other. All the better instruments are provided with such a scale.

Nature of Induction Coil Currents.

In the preceding article the structure of the medical induction coil has been described in detail. We must now, in order to judge of its therapeutic applications, study the nature of the electric currents that are derived from it. When this apparatus is in action, it is capable of generating three distinct currents.

The battery current.

The primary induced current.

The secondary induced current.

The Battery Current.—No attempt is made to use the battery current in the induction coil apparatus for therapeutic purposes. Its function is to supply an electro-motive force in such manner as to create magnetic lines of force in the temporary magnet and exercise an inductive influence upon the coils. In order to effect this so as to secure a succession of induction current impulses, the battery current must be interrupted with more or less frequency, as it is only by varying the number of lines of force that cut across the coils that an induced current is created in them. The "make" and "break" of the battery current, which is effected by the interrupter, is an indispensable feature, therefore, in the induction coil apparatus. And the frequency with which these interruptions in the battery current take place determines, in a great measure, the nature and physiological and therapeutic effect of the induced currents which follow. The battery current should be strong enough to saturate the temporary magnet with a magnetic flux and to successfully withstand the opposing electromotive force which is created by self-induction in the primary and secondary coils when their circuits are closed. The larger the temporary magnet and the greater the resistance and number of turns in the primary and secondary coils, the greater will need to be the electro-motive force of the primary battery used for furnishing this battery current. The battery current (ABBBA') is, of course, a direct or galvanic current, that is a unidirectional current, but it is interrupted or broken as often

as the spring (H) is carried away from the contact (M). The EMF of this current depends upon the kind and number of cells used, and the amount of current depends upon the resistance in the circuit. The quantity of current may vary, therefore, from half an ampere to several amperes, according to the make-up of the apparatus.

The Primary Induced Current.—At the moment the magnetic lines of force which emanate from the temporary magnet as a result of the influence of the battery current begin to cut the turns of the primary coil, an electro-motive force is generated by them in the primary coil, which is opposed to the flow of the battery current and decreases it. When the battery current is interrupted by the breaking of the circuit at the spring vibrator, the inductive influence of this current on the temporary magnet ceases, and there is a sudden withdrawal of the magnetic lines of force which came from this source. This sudden loss of potential creates an induced current in the primary coil which has the same direction as the battery current, but as the battery circuit is open between the contact point and the spring, this current can only traverse that circuit by leaping the air-gap, which it does at times and causes the spark which is seen at this point when the instrument is in action. If another circuit is provided for this current that is induced in the primary coil at the "break" of the battery current, then this induced current at the "break" can be utilized in therapeutic work. And this is the origin of the current derived from the medical induction coil that goes by the name of *primary current.* It is a unidirectional current, but interrupted with a frequency corresponding to the movements of the vibrator. It has the same direction as the battery current, but differs from it in having less quantity but higher electro-motive force. Both its strength and electromotive force can be varied by moving the shield covering the core, or by changing the position of the core itself, if this is made movable.

The primary induced current has in a feeble way the properties of a direct or galvanic current. It is both electrolytic

and cataphoric to a slight degree, but its chief action upon the living organism is as an excitant to contractile tissue and to sensory nerves by reason of the interruptions which cause a sudden variation in potential. The suddenness of this change in electro-motive force makes this current a powerful stimulant for exciting muscular contractions and for arousing the action of sensory nerves.

The Secondary Induced Current.—The secondary coil winding (FFFF) is entirely distinct from the primary and has its separate terminals at the binding-posts (EE′). In some forms of induction coils the secondary coil can be removed from the instrument, and many instruments are supplied with several secondary coils differing in size and length of wire and in the number of turns. There are induced currents generated in the secondary coil both at the "make" and "break" of the battery current. The inductive effect on the turns of the secondary coil at the "make" of the battery current is due to the lines of force from the magnet cutting across them. This current is comparatively slow in its increase to the highest potential because of the somewhat gradual development of these lines of force. The induced current at the "break" on the contrary, because of the sudden withdrawal of these magnetic lines of force, is more promptly developed to its greatest intensity and, of course, is in the opposite direction from the current induced at the "make." The secondary coil current then is a to and fro, or alternating current with the "break" a little greater in intensity but shorter in duration than the "make" current, while the frequency of the alternations or the number of periods depends upon the action of the vibrator or interrupter. The electro-motive force in this current is determined by the number of turns in the coil that are cut by the magnetic lines of force, and the quantity of current is determined by the resistance offered to its flow and the strength of the magnetic flux which induces it. The electro-motive force, when a fine wire of many turns is used in the secondary coil, is much higher than that of the primary induced current, while the amount of current is correspondingly much less. The

alternating character of this current prevents it from being either electrolytic or cataphoric, while its physiological effects depend very much upon the structure of the coil and the frequency of the alternations. If the alternations are very frequent and the coil composed of many turns of fine wire, the resulting current, though interrupted, begins to resemble in physical properties a sinusoidal current. The approaches to and departures from the highest and lowest potential in each period is, by this construction, made more gradual and the effect physiologically is stimulating and yet not irritating. Its effect, therefore, is tonic and sedative on both motor and sensory nerves.

Primary Battery Tests.

Some of the readers of the BULLETIN will recall that in June, 1893, a committee of the American Electro-therapeutic Association on constant current generators and controllers, of which the Director of this laboratory is chairman, undertook by experiments in this laboratory to determine the relative efficiency of such primary batteries as are in common use by physicians practicing electro-therapeutics, and of such other primary batteries as are recommended for this purpose by manufacturers. The forms of batteries that, for the most part, have been subjected to test in the course of these experiments are those which by reason of size are suitable for stationary work only, it being the intention of the committee to follow this investigation by others on portable batteries in which both wet and dry cells are used. The manner in which the cells that were submitted for this test by the various manufacturers were set up and dealt with, the number of cells contained in each series, together with the other conditions that were arranged at the outstart for the conduct of the tests, were clearly set forth in the first report made to the above Association at its Chicago meeting in September, 1893, and were published in Vol. I., No. 1, of this BULLETIN, p. 9, and also in the Transactions of the American Electro-Therapeutic Association for that year, and need not be here repeated.

It need only be said that the conditions there laid down have been rigidly followed during the entire two years in which the tests have been carried on, until now they have been brought to a close by reason of the "exhaustion" of the majority of the plants under investigation. The main object of this inquiry has been to discover the "life" of each of these forms of batteries when used for electro-therapeutic work and to note the manner in which each acted during its service and finally to point out the weaknesses, if any, which the cells exhibited, so that both operator and manufacturer might profit by such information in taking measures to improve and maintain better action in these cells in the future.

The batteries that have been undergoing these tests have been composed of the following forms of cells:

The Partz Acid Gravity No. 3,	30 cells
The Partz No. 5,	50 "
The Laclede "B",	50 "
The "Axo" Leclanche',	50 "
The Fitch Perfect,	50 "
The Law,	50 "
The "Vole" Leclanche',	50 "
The Edison-Lalande,	5 "

Observations have been made daily for two years on all the cells that have continued to furnish a current for that time. The records are too voluminous to be published in these columns. Copies, however, have been sent to each one of the manufacturers who have contributed cells for the experiment, and through them the medical profession will, no doubt, reap the benefit from the facts discovered, for many of the weaknesses in these primary batteries are remediable. The entire report with the conclusions arrived at by the committee will soon be published in the columns of the Journal of the American Medical Association.

Measuring Induction Coil Currents.

Ever since the movement began among electro-therapeutists to introduce instruments and methods of precision into practice that would permit of repetition and verification of results, the necessity for a meter capable of measuring the induction coil currents has been recognized.

The galvanometer or milliamperemeter when introduced into the patient's circuit of a direct and uninterrupted current gives satisfactory evidence of the amount and direction of the current to which the tissues in the path of the current are subjected. For the direct or galvanic current this is the kind of information needed, since it is upon quantity and direction of current that we depend for most of the results that we seek to obtain by means of this current.

If in the use of the induction coil it is the amount of current that is flowing at any given time that needs to be known, there is, so far no instrument devised that is capable of measuring it accurately, or at all. A very delicate galvanometer can give some approximate measurement of the primary induced current, since this is a current of one direction. But by reason of the interruptions the flow of the current at each impulse is too brief to permit the needle to come to rest. The secondary coil current is alternating as well as interrupted and although current meters are in use on alternating dynamo circuits none of these will register the small currents of the secondary induction coil, which seldom exceed twenty milliamperes.

In the physiological and therapeutic action of the induction coil currents the important factors are the amount of current and the electro-motive force of the current. It is to variations in these factors that the effects produced by induced currents are chiefly due. The frequency with which these variations are effected is an element of importance, it is true, but it is a subordinate one. A meter, therefore, that is to be of any material service in regulating the dosage of these currents must be constructed with reference to one or the other of these factors. In other words it should record either the

voltage or the amount of current in the patient's circuit. In view of these facts, such methods as have been in use thus far for measuring these currents will appear crude indeed. To the best of our knowledge there have been up to the present time but two methods employed:

(1) A scale for showing the relation of the primary to the secondary coil.

(2) A graduated rheostat of high resistance.

The first of these methods may serve a useful purpose to an operator using the same instrument from day to day upon the same patient since it enables him to judge somewhat of the comparative strength of current which his patient can bear at different times. This he can do by noting the relative position of the coils as determined by the scale. But there are too many variable factors in the process for it to serve as a means of comparison of effects produced upon different patients.

Changing the position of primary or secondary coil, so that one overlaps the other to a greater or less degree—or, what amounts to the same thing, moving the temporary magnet or changing the position of its shield, if it has one, will modify, it is true, the strength of the induced currents in the coils by exposing the turns of wire to a greater or less number of magnetic lines of force so that a scale marked upon the magnet or shield or alongside the movable coil will serve as a crude indicator of the change made. But this scale is not to be seriously thought of as a measure of either current or electro-motive force. The induced currents depend first upon the strength of the battery or inducing current and second upon the length and number of turns and the size of wire used in the coils—as well as on the size and shape of the temporary magnet. Even if coils of the same maker are always alike in construction, which is seldom the case, the inducing current furnished by the primary battery will vary greatly in strength at different times and so modify the strength of current in both primary and secondary coil. The fixed scale can take no account of such variations, no matter what

their degree—and thus it becomes a measure of capacity only in name.

The attempt has been made by Von Ziemssen and Edelmann to correct at least one of these faults, that is, the variations in the inducing current. By introducing an adjustable resistance in circuit with the primary coil they have provided a means by which the resistance on the primary circuit may be made such as to adapt it to variations in strength in the primary battery and so keep the strength of the inducing current constant (i. e. 300 ma). With the inducing current constant it is assumed that the inducing effect upon the magnet and upon the windings of the secondary coil will be correspondingly constant. The scale accompanying instruments of this construction presumes to be graduated in volts. The accuracy of the calculation by which such a scale of volts is determined in the first instance is open to question. But assuming it is correct this can only remain true for a fixed resistance between the terminals of the secondary coil, when the fact is that this resistance is continually varying in practice where some part of a patient completes the circuit. The calculated voltage on the scale is consequently never, or seldom, the actual voltage on the circuit. The Edelmann "faradimeter," as this is termed, is, therefore, at the best, a cumbersome and expensive arrangement, and in order to secure from it even that degree of advantage that it is capable of giving as a measurement of voltage the coils of all instruments must have identical construction or each must have a scale especially calculated for it.

The second method by which attempts have been made to measure the current delivered by the coil is by graduating a high resistance rheostat placed in series with the coil and with the patient Here the amount of current is shown by a scale indicating the quantity of resistance that is put in or taken out of the circuit. In other words, this, which may be termed the Monell method, attempts to measure the current in terms of ohms where the Edelmann method seeks to express it in terms of volts. It is readily seen that this method also requires constancy in the inducing current in order that the scale may

represent the same values at succeeding applications of the current, for a variation in the inducing force would be followed by a variation in the voltage and strength of the induced currents, and this variation the fixed scale on the rheostat does not record.

It is quite as essential also in any attempt to make use of a high resistance rheostat as a faradimeter that the coils used in all instruments should exactly correspond in structure, or that the scale used should be calibrated for each coil. I am not aware that either this or the constancy of the inducing current has been taken account of by the Monell method. Of course it is presumed that in this method the resistance of the material used in the construction of the rheostat does not change.

Neither the Edelmann nor the Monell method of measurement, even assuming that they are developed to their highest efficiency, are independent of the sensations of the patient for determining the dose of the coil current. Should the current, by chance, be applied to a limb or a part of the body in which both sensation and motion are impaired there would be no positive evidence given by either of these forms of so-called meters that a current is actually passing. In reality, therefore, the sensory or motor nerves are the parts in the circuit that actually determine the strength of current when either of these methods is used. It is our belief that until inventive ingenuity has been able to devise an instrument which can be placed directly in the patient's circuit of the induction coil current and record either the milliamperes or the electro-motive force of that current no satisfactory faradimeter will be forthcoming.

VOLUME III. APRIL, 1896. NUMBER 2.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL

LABORATORY

OF THE

UNIVERSITY OF MICHIGAN.

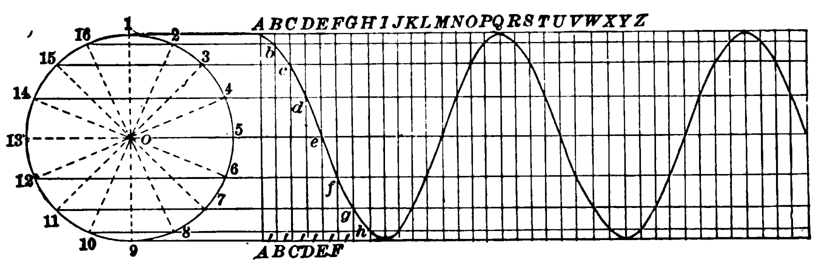
Published Quarterly by The Inland Press, Ann Arbor, Mich.
Subscription Price, One Dollar a Year.

The Sinusoidal Current.

Much has been said in medical journals in the past few years of the nature and action of the sinusoidal current in therapeutics. By a sinusoidal current is meant an alternating induced current in which not only the rise and fall of potential or electro-motive force of positive direction is immediately succeeded, without break, by an exactly corresponding rise and fall of potential of negative direction, but this rise and fall in both directions would, if shown with accuracy in diagram, describe a sine curve. The accompanying illustration, taken from Prof. H. S. Carhart's work on Elementary Physics, with the permission of the author, well illustrates this form of curve.

Mathematically considered this curve may be defined as one resulting from two rectilinear motions at right angles to each other; the one being a uniform rectilinear, the other a simple harmonic motion. This last named motion is one well illustrated by the common pendulum, which moves most rapidly at the middle of its swing, decreasing in rapidity as it

approaches the ends. The figure represents diagramatically a combination of these two motions. The equal spaces made by the vertical lines at the right represent the progress of the uniform rectilinear movement from left to right, while the spaces between the horizontal lines represent the simple harmonic movement or sine displacements. These spaces on the vertical lines are obtained by dividing the circle at the left into 16 equal arcs and drawing horizontal lines through the points marking their boundaries, as 1, 2, 3, etc. Now if we assume that this circle is made to revolve at right angles to the plane of the paper with the line O, 5, e, for its axis, one revolution of the circle will correspond to a complete vibration of a pendulum, and if, while revolving, the circle moves from left



to right at a uniform rate along the axis O, 5, e, then the displacement of any point upon the margin of the circle from the middle line is proportioned to the sine of the angle of rotation on the circle. Thus if we take the point 5 and rotate it through the arc 5, 6, the vertical displacement of the point 5 will be the sine of the angle of rotation 5, o, 6. Again the vertical displacement from 5 to 7 is the sine of the angle 5, o, 7. It will be seen that these sines correspond to vertical distances between the horizontal lines at the right of the circle and that the diagonal lines in the parallelograms are but the resultant of these two movements of the circle.

The sine curve can be platted by completing these diagonal lines through one entire revolution of the circle.

The current derived from the secondary circuit of an induction coil has been shown to be alternating, but the positive and negative alternations differ considerably in electromotive force and the gradations from zero to the greatest

difference of potential in either direction are not regular and uniform but quite the contrary. Moreover, the secondary current of the induction coil is interrupted, the time interval occupied by the interruptions exceeding considerably that consumed by the passage of the current. In these respects the secondary current of the induction coil differs from a sinusoidal alternating current in its physical properties, and these physical differences have of necessity a corresponding difference in physiological and therapeutic effects. By increasing the length and number of turns of the secondary coil and increasing the rapidity of the vibrations of the interrupter the current derived from the secondary coil of the induction apparatus is made to approach more nearly in physical and physiological properties the sinusoidal current as at present used.

The magneto-electric apparatus, which some years ago was not infrequently seen in physicians' offices, likewise creates an alternating current. This "magneto-generator" consists of a permanent magnet in front, or at the sides, of the poles of which, two spools of wire are made to revolve by means of a crank turned by hand. The alternating current generated by this little machine, while it shows no interruptions when the coils are revolving, is yet quite irregular as compared with a sinusoidal current, since the lines of magnetic force emanating from the poles of the magnet cut the turns of wire in the coils as they revolve, in such manner as to create no uniformity in the increase and decrease of the induced currents. It is, however, only in this feature of construction that this well-known magneto-electric machine differs from several of the sinusoidal machines that are now being manufactured for therapeutic work. In these latter the attempt is made, with more or less success, to secure such uniformity in the increase and decrease of the number of the magnetic lines of force that cut the coils as they revolve, that the electro-motive force generated will describe the sine curve. This desirable result is the more nearly attained according as the permanent or electro-magnets used are so shaped as to furnish to the coils a strictly uniform gradation in the strength of the magnetic field as they enter and leave it. Although the modern appar-

atus shows great progress in skill and workmanship yet it is quite probable that no so-called sinusoidal machine has yet been constructed that describes accurately in its action the sine curve.

The alternating current dynamos now used so extensively for lighting incandescent lamps furnish a current which is roughly sinusoidal and can be utilized by physicians who have access to it and have some form of apparatus, like the McIntosh Current Controller, suitable for modifying its strength and voltage. As the speed of these dynamos, while in action, is quite uniform, the number of alternations do not vary much and the frequency is often much less than is wanted in therapeutic work, being only about 124 alternations per second. It is convenient and oftentimes quite desirable to have an apparatus for the generation of a sinusoidal current so arranged that the operator can vary the frequency of alternations, the electro-motive force and the current at will, and this is possible with some of the machines now manufactured.

Physiology and Therapeutics of the Sinusoidal Current.

There are several physical peculiarities possessed by the sinusoidal current which help to make its action on the body different from that of other forms of current. As has been seen from the foregoing description the increase and decrease of potential in this form of current is gradual and uniform and never abrupt nor sudden in its change. It is no doubt to this feature of the current that its peculiar action on the sensory and motor nerves is mainly due. The sensory and motor mechanism of the body is capable of adjusting itself to a considerable range of difference in external conditions without serious disturbance or discomfort, provided the change is not too sudden or violent. Even though there may be many periods of alternation of current per second and the electro-motive force be quite high, yet the action of nerve and muscle is still capable of responding to such variations without disagreeable reaction provided the

change in strength is gradual. The number of alternations per second, the degree of electro-motive force and the quantity of current are, no doubt, each important factors in determining the physiological and therapeutic effects of this current, but these are not so peculiar to it as is this feature of uniformity in change. The effect of this special feature of the sinusoidal current is to lessen the disagreeable effects of electric excitations both on the sensory and motor mechanism. The same amount of stimulation to muscular action can be aroused as by any other equally powerful means, without the accompanying pain and consequently without the shrinking and apprehensiveness on the part of the patient which other forms of excitation arouse. In this lies the chief advantage of the sinusoidal current over the current derived from the secondary induction coil, while in many other respects these currents are similar in action.

For exciting to vigorous action muscular tissue, therefore, whether it be the voluntary or involuntary variety of muscle, the sinusoidal is the current *par excellence.* Such frequency of alternations can be used as will adapt the excitation to the requirements of the muscular structure. The comparative painlessness of the applications permits the use of greater electro-motive force and more current than can be used either from the induction coil or the primary battery, so that the physiological action of the muscles is more thoroughly aroused than by the use of either of these other forms. The more nearly the curve of current conforms to the sinusoidal the less will there be of effects resulting from polar action. Electrolysis and cataphoresis will be avoided and the changes brought about in the tissues to which the current is applied will be mainly those which are normal to their function; the effect of the current being to arouse that function to greater activity. When we consider how many of the normal processes of the body, such as assimilation, circulation, secretion, excretion, locomotion, etc., depend directly upon muscular tone and vigor it will be seen at a glance what a wide range of therapeutic application is possessed by this form of current in the field of muscular excitation alone. It has been highly spoken

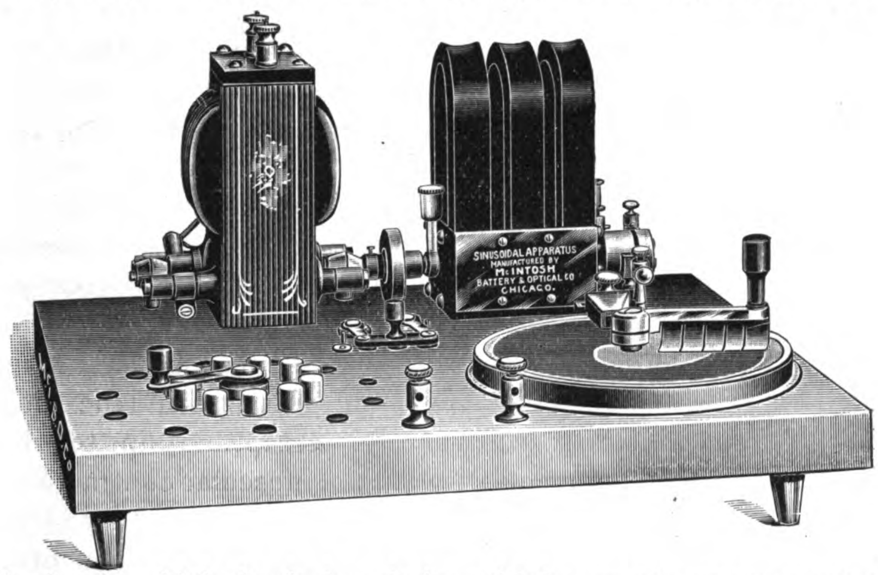
of by many competent electro-therapeutists as a means for improving the nutrition and growth of muscular tissue whenever it is failing from lack of proper excitation.

General muscular weakness, local paralysis or paresis, lack of intestinal peristalsis, vaginal and rectal prolapsus, due in whole or in part to lack of muscular tone, and vaso-motor debility are some of the conditions in which the form of current has proved especially beneficial.

It has been said that the sinusoidal current is remarkable for the little amount of sensory excitation it causes, and so permits powerful muscular contractions without discomfort. Further than this it serves to allay pain. It is as much if not more serviceable in this way than is the current derived from the secondary induction coil of many turns. Apostoli and others have borne strong testimony to the fact that the greatest success they have attained with this form of current has been in allaying the pains that occur in connection with the pelvic organs. The pains caused by uterine inflammation, pelvic cellulitis, ovaritis, salpingitis and congestion are quickly allayed by it. Neuralgic pains are relieved and those of spinal irritation. Marked effects on tissue metabolism have been noticed also as indicated by increased consumption of oxygen and more rapid elimination of carbon dioxide. These effects are in all probability secondary to and dependent upon the increased muscular activity and analgesic influence of the current.

The McIntosh Sinusoidal Apparatus.

The instrument here illustrated is the result of the most recent attempt by manufacturers to provide a source of sinusoidal current for therapeutic work. It consists of a small motor wound for the 110 direct current and has connected with it a special rheostat for controlling its speed. The shaft of the motor is extended and carries on this extension the armature of the sinusoidal machine, thus making a very convenient and compact arrangement, doing away with belts and pulleys. The armature carrying the windings of the coils



of wire in which the induced sinusoidal currents are generated revolves between the poles of a group of three powerful permanent magnets, the pole pieces of which are so shaped as to secure a uniform gradation in the lines of force which cut across the revolving coils on the armature. From the coils the current is conveyed to binding posts on the base of the instrument, but before the circuit reaches the binding posts a graphite rheostat is interposed regulating the strength of the current. This arrangement makes the apparatus complete. It is only necessary to connect the binding posts on the top of the motor with a suitable direct current circuit such as the Edison incandescent light circuit, or a street car or power

dynamo circuit of higher voltage, provided sufficient lamp resistance is introduced so as to reduce the potential, and then complete the patient's circuit by attaching electrodes to the binding posts on the base. The rapidity of alternations and consequently the voltage is readily modified by the rheostat in the motor circuit while the strength of current can be graduated independently by means of the rheostat in the patient's circuit. Two additional brushes are in contact with a commutator on the outer end of the armature shaft and these serve to deliver the current generated as a current in one direction, instead of alternating, when this is desired. This direct current can be thrown into the patient's circuit by a proper movement of a switch which is provided on the base. By connecting the motor of this instrument with a power circuit in this laboratory, the current supplied to the motor registering by a Weston meter 120 volts, we were able to run the armature shaft at the speed of 5280 revolutions per minute when all resistance was off the motor circuit. The number of alternations would of course be twice this, or 10560 per minute; or 176 per second. By diminishing the speed of the motor any less number of alternations per second could be obtained. The strength of current could be modified from that which was barely perceptible up to that which would produce the most powerful muscular contractions, and yet at no time was the sensation produced, either in the integument or muscles, disagreeable or painful as is so often the case with the current from the faradic machine. For producing an agreeable and effective muscular massage or stimulation this form of apparatus appears to have no superior. The electro-motive force that is developed in the patient's circuit depends upon the speed with which the armature is made to revolve. At the highest speed attainable the Weston alternating voltmeter registered 110 volts and at the slowest speed, 33 volts. If a lower electro-motive force with great frequency of alternations is desired this could be readily accomplished by having a less number of turns in the armature winding.

The direct or galvanic current that is furnished by this instrument is of course not uniform in potential but varies in

intensity at each revolution of the armature. With this also the speed determines the amount of current. The milliampere meter showed this current to be 10 milliamperes at high speed, and when a patient was between the electrodes and the direct current was carried up to the limit of tolerance the amount of current was between three and four milliamperes. Electrolytic work was readily done by this direct current but the comparatively high electro-motive force that was required to get sufficient current for electrolysis might in some instances in actual practice prove disagreeable to a patient; and the direct current derived from this apparatus cannot be made to take the place entirely of a galvanic battery or other sources of direct current.

The Kennelly Sinusoidal Machine.

Of the various machines submitted to us for trial, the one designed by Mr. A. E. Kennelly, the well known electrical engineer, is worthy of special mention. This machine bears a striking resemblance to the ordinary multi-polar alternating current dynamo, but on closer examination it will be found that both the primary (exciting) and the secondary windings are placed upon the field frame. The field frame is of laminated iron supported by castings and has twelve poles; on each pole is a spool with two windings of wire. The inner has eight layers of fine wire and the outer, two layers of coarse. All the coarse wire windings are connected in series in such a way that the magnetic polarity produced shall be alternately north seeking and south seeking, when a direct current is sent through this circuit.

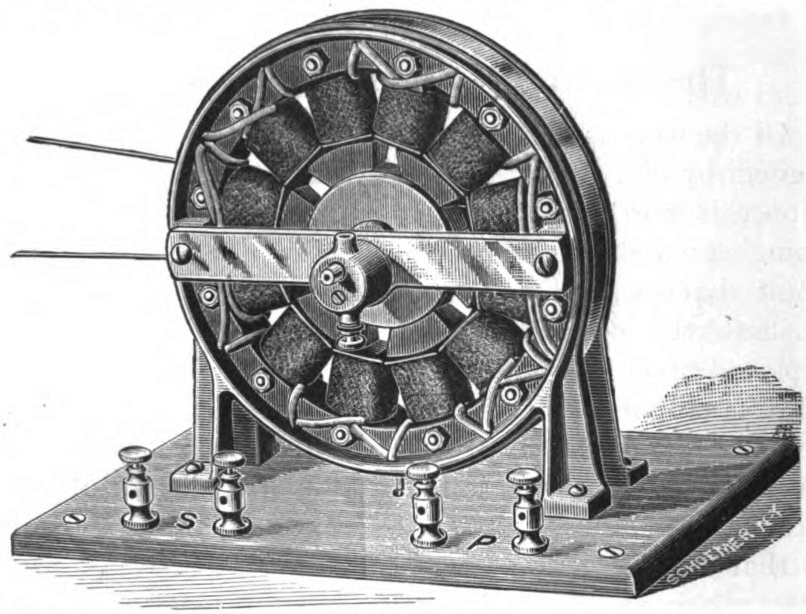
The armature is composed of several discs of sheet iron firmly fastened together, having slots and projections as will be seen from the figure. This armature is just large enough to rotate freely within the concentrically arranged pole pieces. Bearing in mind the relation of the secondary coil to the pole, it is evident that anything causing an increase or decrease of magnetic lines of force through the pole, i. e., any variation of the magnetic flux, will induce a current of electricity in the

secondary. The E. M. F. of this induced current will depend upon the number of turns of wire and the rate of increase or decrease of the magnetic flux. In this machine the direct current passing through the coarse wire windings constitutes the magneto-motive force; this remaining constant, the magnetic flux will vary inversely with the reluctance, i. e., the "magnetic resistance."

The law of the magnetic circuit may be stated as follows:

$$\text{Magnetic Flux} = \frac{\text{Magneto-motive force}}{\text{reluctance.}}$$

The reluctance of air being very great as compared to that of iron it follows that the magnetic flux in any pole will be suddenly increased when the air-gap or slot opposite that



pole is displaced by the iron projection of the rotating armature, thus inducing a current in one direction and the next instant when the iron projection is passing and the next slot is coming opposite the pole there will be a decrease of magnetic flux and a corresponding current in the opposite direction.

The slots and projections of the armature are so proportioned that the graphic representation of these alternations of the current closely approximate the true zinc curve, thus giving the so-called sinusoidal current. Twenty-four alterna-

tions or twelve complete periods occur at each revolution of the armature; a speed of 80 revolutions can be attained and will therefore give 1920 alternations per second or a frequency of 960.

The E. M. F. of the secondary current varies with the amount of current flowing in the primary, i. e., with the magneto-motive force. This fact offers a convenient method for regulating the voltage of the secondary without varying the speed. The primary current may be derived from primary batteries or from street mains and should be passed through a rheostat so that it may be varied from two amperes to the small fractional part of an ampere.

The E. M. F. when the secondary is open varies directly with the speed and the strength of current in the primary circuit. With one ampere in the latter circuit, the limit of E. M. F. in the secondary is about 50 volts, which is about 70 volts at the top of each wave, the 50 volts representing the average electric pressure. On short circuiting the secondary, the voltage is reduced nearly to zero, but in practice this will not occur except by accident. The E. M. F. of the secondary passing through the body of a patient will vary with the resistance offered, but because of the comparatively high resistance offered will practically amount to that recorded by a voltmeter in open circuit.

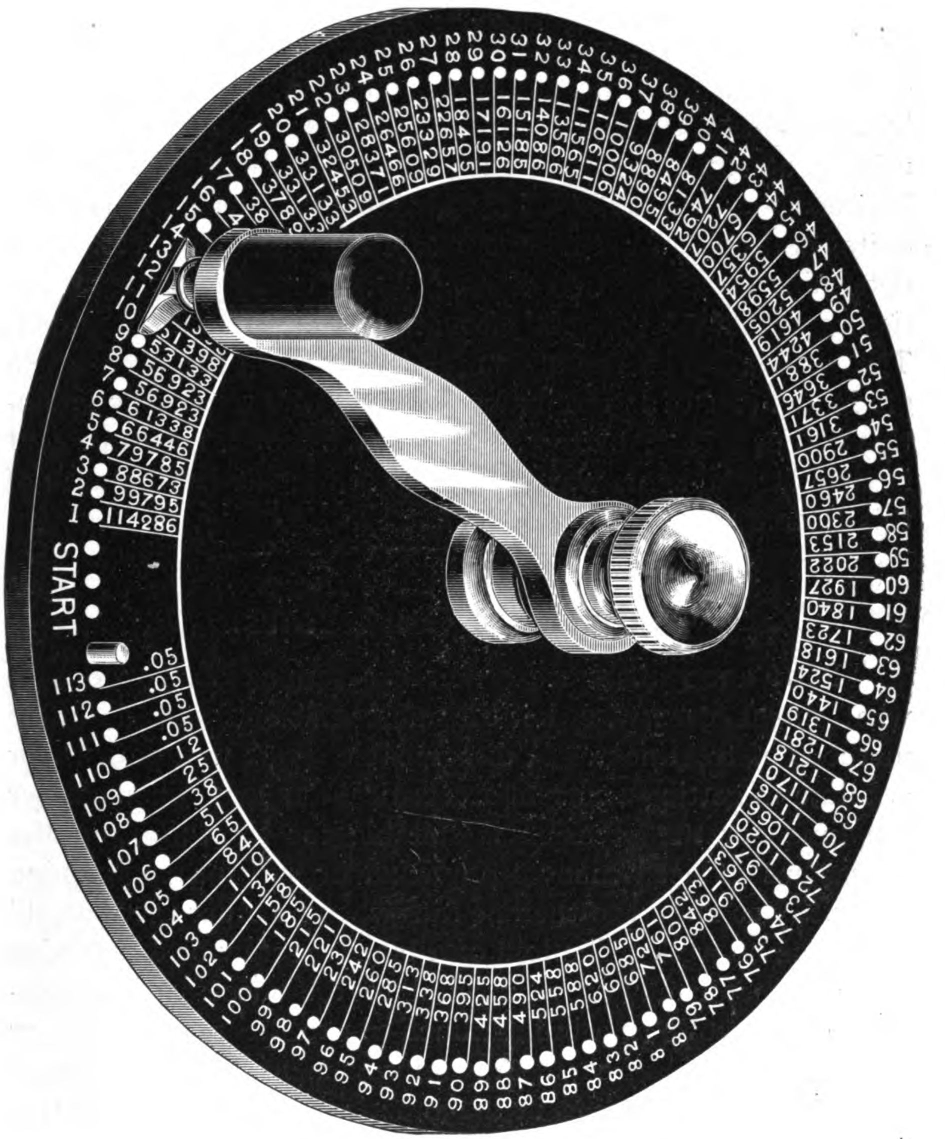
In comparing this machine with others built for the same purpose the following are some of the facts to be considered:

The Kennelly machine requires both a motor for running and some independent source of direct current for exciting the fields. Neither of these are necessarily disadvantages as the physician may possess accessories, and even if he should not they may be procured at a cost probably not exceeding that of those furnished with other machines. Further as has been shown the independent exciting current can be so controlled as to vary the E. M. F. of the secondary without affecting the rate of alternations. This is a decided advantage and one not possessed by some other machines which we have examined. Again, it has the very desirable high rate of alternations attained by few others which can be varied by the motive powers employed without materially changing the voltage.

Improved Rheostat.

Any improvement in electro-therapeutic apparatus looking toward greater refinement and accuracy in determining the results obtained by it is hailed with delight by the progressive physician, provided it is both simple and serviceable. In limiting the number of unknown terms in attempts at the solution of a problem the solution is made more certain and conclusive. Rheostats are not only convenient but have now become essential to the successful handling of both direct and induced currents, and the dry rheostat has many points of superiority over the liquid form for this purpose. One great objection to both the liquid and dry rheostats, with the exception of those made of wire which, when of very high resistance are both bulky and expensive, has been the fact that the amount of resistance which they interpose in the circuit was unknown and therefore they served no other purpose than to furnish a convenient means for increasing or diminishing the current when a greater or less quantity of such resistance was used. For this purpose they are of much service and are now quite generally employed in the patient's circuit of both the galvanic battery and the induction coil. Recently attempts have been made to extend the usefulness of these rheostats, when made of material sufficiently constant in resisting capacity. A notable instance of this attempt at improvement is shown in the accompanying cut of the well-known Willms' Dry Current Controller, made by the Chloride of Silver Dry Battery Company. At our suggestion they have, at much pains and expense, perfected this rheostat by determining and marking the scale of resistances which it furnishes, in ohms, at each contact of the radial arm in its path around the periphery.

This improvement greatly enlarges the usefulness and increases the satisfaction in using the rheostat, especially in the patient's circuit of the constant or galvanic current, for aside from the service it renders, as formerly, in readily graduating the amount of current given the patient, it can now be utilized for determining the resistance of that part of the


START

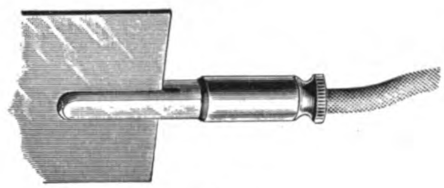
patient's body which completes the circuit between the electrodes. In any application of the constant current where this graduated rheostat is in use, if the E. M. F. and current are known the entire resistance in the circuit can readily be obtained from Ohm's law by dividing the E. M. F. by the current and if from this entire resistance the amount furnished by the rheostat is subtracted, the remainder will give, approximately at least, the resistance of the body of the patient between the electrodes. This is a quantity which it is often quite desirable for the operator to know. He can then determine the proportion of energy that is expended upon the tissues treated independently from the entire amount consumed. The graduation is also of much service when the rheostat so graduated is used in the patient's circuit of a secondary induction coil or faradic battery. But this use of a rheostat, that is, as a faradameter, was fully discussed in the last number of this BULLETIN.

Convenient Connectors.

Petty annoyances are oftentimes serious obstructions to what might otherwise be the most efficient and desirable methods of treatment. A disagreeable shock to a patient, or a failure in getting a current at a critical moment, when neither the time nor the occasion is suitable for searching out the cause, has induced many a physician or surgeon to abandon electricity as an aid to therapeutics when no other agent would serve him so well. The loss of a binding screw or a defective cord conductor may prove as vital to the success of electro-therapeutic work as a broken linch-pin to the proper running of a moving train of cars. Any improvement, therefore, which will avoid such obstacles in the practical workings of electro-therapeutic apparatus is a blessing to both physician and patient. The American Electro-therapeutic Association has already done much good by securing through the recommendations of its committee on Electrodes some uniformity among manufacturers as to the cord tips that are furnished. It now remains for manufacturers to abandon as far as possible the

binding post and screw as a means of connection between the cord tips on the one hand and the battery contacts and electrodes on the other. A very simple and efficient substitute can be adopted for the old form of connection by which all of the annoyances incident to it can be avoided. By the use of

A



B

B[1]

an universal spring slot-connector, such as is shown in Fig. A, a perfect contact can be readily made with corresponding simple terminals on batteries and electrodes. For some time spring slot-connections have been made both for cord tips (as B) and electrodes, but the adoption of the suggestion that an universal connector take the place of all these special devices would not only vastly improve but at the same time greatly simplify the construction of electrodes and battery contacts. In addition to this the expense of electrodes by reason of this simpler construction would be lessened. Some time ago we had a number of these universal connectors made for use in this laboratory by the McIntosh Co., of Chicago, and we cannot speak too highly of the comfort and convenience which their use has afforded us.

Notes.

Electro-Therapeutic Practice.

The practice of electro-therapeutics is no longer of necessity wholly empirical. In electro-physics and physiology there is now established so broad a foundation of fact that they furnish a solid basis on which to establish a rational therapeutics. Any working manual that, in its conception, disregards this and undertakes to lay down rules of procedure that have no other reason for their existence than the author's "say so" will fail of patronage. The little work of Neiswanger, termed *Electro-Therapeutic Practice*, which has been recently published under the auspices of the McIntosh Battery and Optical Company, and is sold by them, we discover to be an attempt to institute a sound method. The suggestions it contains as to the ways and means to be employed for adapting electricity to the cure of a great variety of disorders are, for the most part, based on well-known principles of physics and physiology. Such a manual deserves the favorable reception that is being accorded it by the members of the medical profession. Its practical hints and lack of unnecessary verbiage commend it to the busy practitioner.

The Sciagraph.

The service which electricity rendered medicine and surgery, both in a direct and indirect way, was already great. But now as a generator of Rontgen rays, making possible the sciagraph, its field of usefulness as an aid to surgical diagnosis has greatly extended its usefulness. There is much reason to hope, from increase of knowledge as to the gradations in opacity of the different tissues of the body and better appliances for generating the Rontgen rays, that not only the bones but also the softer tissues of the body, both normal and abnormal in structure, will submit to inspection by this means.

VOLUME III. JULY, 1896. NUMBER 3.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN.

Published Quarterly by The Inland Press, Ann Arbor, Mich.
Subscription Price, One Dollar a Year.

Diagnosis by Röntgen, or X-Rays.

In the prospectus which appeared in the first number of this BULLETIN it was stated that it would be regarded as the province of the editor to discuss electric action in whatever form or mode of generation it was found to promise aid in the practice of medicine or surgery. Any advance or improvement in methods of diagnosis is a substantial gain. Electricity had already done much to render the diagnosis of disorders of the muscular and nervous system and pelvic organs more exact, but recent discoveries of the effect of the action of high tension currents of electricity in vacuum tubes have greatly enlarged its field of usefulness in diagnosis and it now bids fair to be the agent by means of which both surgeon and physician will be able to add the sense of sight to that of touch and hearing, in determining the state and condition of the deep seated tissues of the body.

No one can as yet set any limit to the practical applications that will be made of Röntgen rays in revealing what to

human vision is otherwise unseen. Already the members of the medical profession have found from them such help as to give promise that the date of Röntgen's discovery will mark a period of advance in medical science as important as the discoveries of Jenner or of Lister. Already enough has been done to show that not only all parts of the bony skeleton, with its defects are soon, by this process, to be portrayed in minute and exact detail, but the structure of the softer tissues and organs, also, their normal outlines and density, together with their departures from the normal will likewise be revealed.

So far as is at present known the creation of these peculiar rays by means of which the human eye is enabled to see, pictured upon fluorescent screen or photographic plate, the things of the body hidden beneath the surface, is dependent upon the action of electric currents.

Here arises another demand upon the medical profession to become practically familiar with the phenomena of electric physics. In so many ways is a working knowledge of this science helpful to the physician and surgeon that it is surprising that ample facilities for teaching it are not provided in the curriculum of every first-class medical college. The time is not far distant when such neglect of a branch so essential to a full equipment in medical skill will be no longer tolerated by the progressive student.

There are certain pieces of apparatus that are indispensable to the production of Röntgen rays and for utilizing them for purposes of diagnosis. These are:—

An appliance for generating a suitable electric current.

A Crookes tube.

A fluorescent screen or photographic plate.

Since the announcement by Röntgen of his discovery each portion of apparatus needed in the process has been by numerous able investigators subjected to a variety of experiments with a view of increasing its efficiency. And such volume of contributions and suggestions, of great or little value, is now pouring out upon us through the columns of the

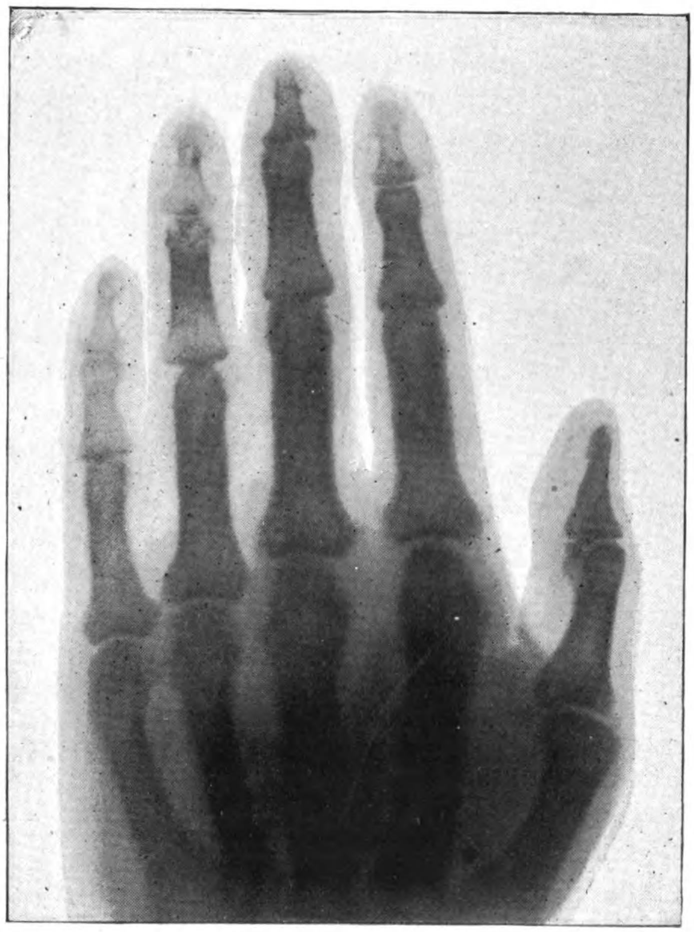


Figure I.

scientific journals and popular magazines, from the pens of these men or their faithful reporters, that the reader can scarcely keep abreast of it. We will undertake, however, for the benefit of those of our readers who have not access to all these sources of information, to briefly present what seems to be, at the present stage of progress, the facts concerning the nature of Röntgen rays, the best form of electric generators, the best form of Crookes tubes and the best methods for getting temporary or permanent diagnostic results from them.

Nature of Röntgen Rays.

When Professor W. C. Röntgen first announced the results of his researches on a "new kind of ray" he advanced the following conclusions which he had reached as proof of his conviction that these rays were distinct in nature from cathode or Lenard rays or any other form of radiation hitherto described:

They are not reflected,

They are not refracted, but follow absolutely straight lines,

They cannot be polarized,

They do not respond to magnetic influence,

They are incapable of raising the temperature of substances through which they pass or upon which they fall.

These peculiarities, assuming them to be facts, gave to this manifestation of energy a distinctive character and forbade classifying it with any phenomena with which science was already familiar. The discoverer inclined to the view that these phenomena were due to longitudinal waves in the ether but with commendable caution he contented himself with designating them as X-rays, or rays of undetermined nature or value, until his conclusions could be verified by others and more facts be gathered.

Certain phenomena resulting from the action of these rays showed them to be co-related to light and electricity since under suitable conditions they were found:—

To produce shadows,

To cause chemical action,

To create fluorescence,

To dissipate electric charges, whether positive or negative.

Never in the history of the world has greater activity been exhibited in an attempt to bring that which is but partially known into the realm of that which is better known and to determine where it is to be grafted on to the tree of knowledge. The discoverer's conclusions have been put to the test in a thousand different ways by well trained physicists and it reflects credit on the extreme accuracy of his labors that even after six months of trial few have surpassed him in the ingenuity of the methods employed or the clearness of the demonstration given. Most of the conclusions arrived at by Röntgen, upon which he based his opinion as to the distinctive character of these rays, not only remain unrefuted but, on the contrary, they have received abundant confirmation from the ablest physicists of the day.

So far only one of these conclusions has been proved erroneous. The Röntgen rays have, by Tesla and Rood and perhaps by others, been reflected. Professor Rood, of Columbia College has proved conclusively that X rays are reflected by platinum, while Nikola Tesla has gone much further and demonstrated not only the reflecting power of platinum but of magnesium, zinc, lead, tin, brass, copper, nickel and other metals, as well as of a number of non-metallic substances. An interesting fact has been disclosed by these researches of Tesla and one that gives promise of future revelations of great importance. It was discovered by him that the metals exhibited a reflecting capacity to Röntgen rays corresponding to their position in the "contact series" of electric potential, and from this discovery he has drawn some interesting inferences.

The overthrow of Röntgen's conclusion as to the non-reflectibility of these rays gives strength to expectation that ultimately they will be found to conform to the known laws

governing finely divided matter moving with great velocity or the transverse electro-magnetic vibrations in the ether, such as ordinary light. That they may be of the latter nature and yet invisible to the human eye is by no means remarkable since it has long been known that there are rays at both extremes of the spectrum of sun-light, as well as of many forms of artificial light, which cause heat, chemical changes, fluorescence etc., and yet give to the human eye no evidence of light.

The rays with which we are familiar in the spectrum which most closely resemble in their properties the X-rays are those beyond the violet and are known as the ultra-violet rays.

There may be said to be three theories or hypotheses at present entertained concerning the nature of the X-rays, each of which has its adherents.

1st. That they are longitudinal waves or vibrations in the ether.

This is the view toward which Röntgen himself inclines and the strongest arguments in favor of it seem to be that the rays cannot be polarized or refracted.

2d. That they are of the nature of ultra-violet light, electro-magnetic vibrations, or transverse vibrations in the ether.

This view is sustained by the facts that the X-rays, like ultra-violet rays, effect chemical decomposition, cause phosphorescence and fluorescence and bring about the discharge of negatively electrified bodies.

Many physicists incline to this view and among them Elihu Thomson, who says: "May not the Röntgen rays be ordinary transverse electro-magnetic waves in the ether as are light waves, but of such high pitch, relatively thereto, as to be beyond the vibration period of atoms in the molecules of ordinary matter, and that, as a consequence of such high pitch they can neither be reflected nor refracted, but can travel through bodies in the assumed free ether between the molecules? It might easily be that, when obstructed by the

molecules, absorption takes place from internal refraction or reflection, and absorption would then depend on the amount of matter traversed, as measured by its density and thickness."

According to this theory it is thus molecular absorption that must account for the difference in shades cast on a fluorescent screen or photographic plate by different substances placed in the path of the rays.

In this connection it may be well to recall the words of Prof. A. E. Dolbear, which appeared in a communication to the Franklin Institute, of Philadelphia, when this subject was under discussion in February last: "As to what was generally known about the fundamental principles it may be said that it was not new to photograph by waves either too short or too long to be visible. Photography can go on whenever fluorescence is possible, and ultra-violet waves have long been known to be effective for that purpose. Dr. Draper, fifty or more years ago, got photographic effects in the region beyond the red; and Captain Abney, in England, long ago photographed the whole spectrum a long way above and below the visible part. Hence photographing with invisible rays, either long or short, is not new.

"As to the interpretation that may properly be given or attempted it may be too early to do more than believe very gently. It is evident that a phenomenon involving phosphorescence, fluorescence, photography, transparency and opacity, long and short waves, their origins and properties, is tolerably complicated; but for myself I should say, that every effort should be made to find the explanation with the transverse waves we know, and take the longitudinal waves only as the last resort. When one reflects upon the well-known phenomenon, flourescence, that is not only the transforming of short waves to longer ones, as in eosin, but also the transforming of long waves into shorter ones, as happens with chlorophane, which changes waves much longer than the red rays into emerald green waves, it is entirely within proper bounds to expect that rays made too long to be appreciably

refracted can act upon a phosphorescent body so as to produce waves capable of doing photographic work."

3d. That the Röntgen effects are due to a stream of matter in a finely divided state moving with great velocity; this state of matter having been brought about by its being subjected to a high electric potential in a vacuum and the division into finer particles being the result of impact.

This is the hypothesis of Nikola Tesla and though it is a novel opinion and he is practically alone, as yet, in entertaining it, nevertheless so clear-sighted and demonstrable have been his ideas, thus far, and so successful has he been in deriving practical results from them, (since his are among the very best sciagraphs yet made,) that his views are entitled to great respect. He says: "The rays consist of streams of minute material particles projected with great velocity. The lumps of projected matter are by impact further disintegrated into particles so minute as to be able to pass through the walls of the bulb or else they tear off such particles from the walls or other surfaces against which they are projected. An impact and consequent shattering seems absolutely necessary for the production of Röntgen rays. The vibration, if there be any, is only that which is impressed by the apparatus, and the vibration can be only longitudinal."

We have not space to give to a full exposition of Tesla's theory but it is upon this hypothesis that his results in obtaining reflection were worked out and holding to it firmly, he confidently expects to find these streams of material particles diverted by the influence of magnets, which if found would be another proof that he is on the right track.

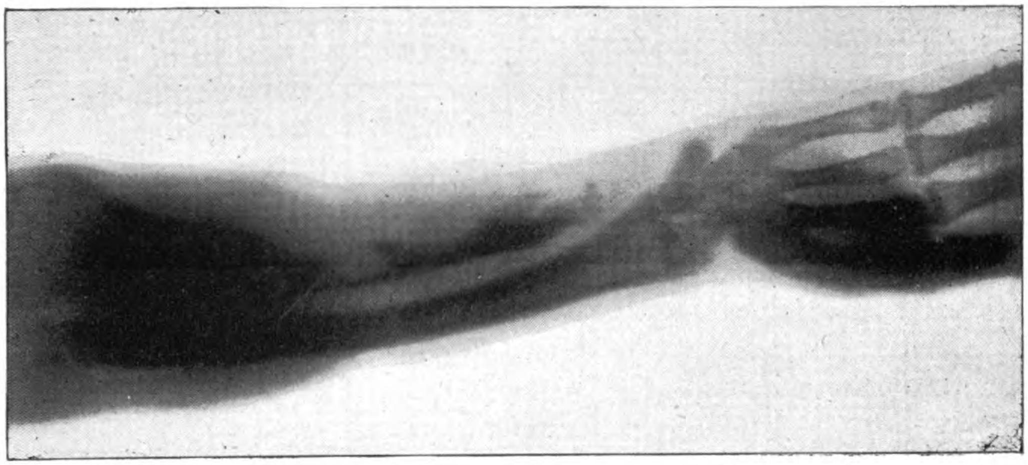


Figure II.

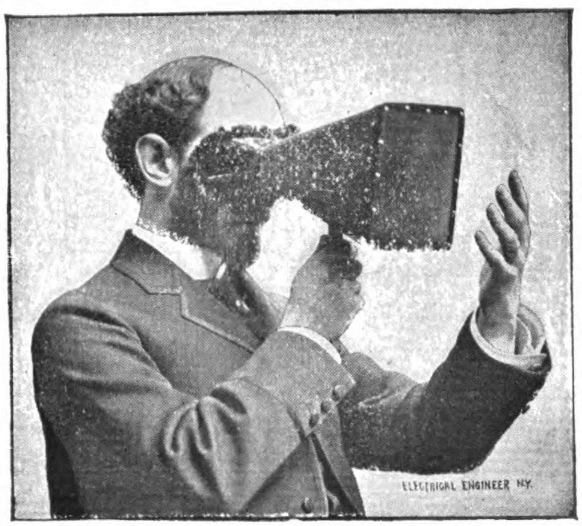


Figure III.

Electric Apparatus for Röntgen Rays.

There are three forms of electric apparatus which have been used to create X-rays—

The ordinary induction coil;

The static or influence machine, and

The disruptive discharge coil.

When we say the ordinary induction coil we do not mean one of ordinary capacity, but one of the ordinary form of construction, the Ruhmkorff coil pattern, with a vibrating, or what is better, a rotating commutator break. This form of electric generator has been used more than any other by those who have experimented with X-rays. The interest in this subject has stimulated manufacturers to produce excellent instruments of this kind until now very reliable Ruhmkorff coils, capable of giving a six, eight or ten-inch spark between the secondary terminals can be obtained for about one hundred dollars.

It may be safely said that a high potential capacity in the electric generator is the first essential to successful X-ray work. So that if a Ruhmkorff coil is used its capacity should be considerable. One giving a three or four-inch spark will serve for generating rays capable of making shadow pictures of the extremities of the body but stronger action is required if the thorax, abdomen or pelvis needs to be traversed by the rays. It is best to take the initial current used to excite the coil from some constant and uniform source of supply as storage batteries or a direct current dynamo circuit as that of the Edison incandescent light current. The use of a McIntosh Current Controller in the dynamo circuit would serve to adapt the current to the needs of the coil. The intensity of current needed depends very much upon the condition of the tube that is used, but with a coil of large capacity the action of the coil can be varied to suit the requirement of the tube.

A Static Machine, when run by a motor, and constant in action is a good Röntgen ray exciter because of the high potential it creates. It is the current resulting from induction in

the outer coating of the Leyden jars attached to the prime conductors of the static machine that is used—the so-called "static induced" current of Morton. Rather more care is needed to preserve the tubes from perforation when using the static machine as a generator than when using the coil since there is liable to be considerable variation in the strength and volume of the sparks between the prime conductors even with the same spark-gap interval. A four or six plate machine with plates of from twenty-four to thirty-six inches in diameter, if its action is good, will serve very well as an X-ray producer. Elihu Thomson has shown some very good sciagraphs where the source of current was a Wimshurst Machine having but two plates sixteen inches in diameter.

But if we are to depend upon Röntgen rays and sciagraphs or fluroscopes to aid us in diagnosis there must be no limit to the quantity or penetrating power of the needed rays. Both the Ruhmkorff coil and the static machine have their limitations. In the former they are due to its mechanical construction and in the latter the expense and lack of constancy in action. Some form of cheaply constructed disruptive discharge coil of the Tesla or Thomson type which could be attached to an alternating dynamo circuit, such as is now so universally employed for illuminating purposes, gives promise of meeting the requirements in furnishing a convenient and reliable source of electric energy of any potential desired for exciting the vacuum tubes. We are now having such a disruptive discharge coil and condenser made at this laboratory with which we hope to get much better results than we have so far obtained from the induction coil.

"By far the best results are obtained by using a high-frequency discharge through the tube. This is conveniently done by exciting the primary of the induction coil from a 50 volt alternating circuit at, say, 15000 alternations per minute. The secondary terminals of the induction coil are led to a battery of Leyden jars through the primary coil of a Tesla induction coil immersed in oil. The secondary terminals of the Tesla coil are then connected directly to the Crookes

tube. Under these conditions torrents of high frequency discharges pass between the discharging knobs of the induction coil which are separated to the distance of, perhaps, 5 millimeters, the frequency being determined by the capacity and inductance of the Leyden jar circuit including the Tesla primary. These high-frequency discharges induce in their turn high-frequency and high-potential discharges in the tube. In such cases both electrodes of the tube are alternately cathodes, and the glass wall opposite to each electrode becomes fluorescent and therefore the source of Röntgen rays." (Houston and Kennelly.)

Vacuum Tubes.

Perhaps no part of the apparatus required, in the present stage of our knowledge, for the production of Röntgen rays has received so much attention as the vacuum tubes in which the antecedent cathode rays are generated. A volume could be written upon this subject and what can be said in a few paragraphs will perhaps to some appear very meagre. Those who wish to investigate the subject more deeply will need to examine the pages of the electrical and scientific journals issued during the last six months, especially for the fruits of the labors of such men as Tesla, Edison, Elihu Thomson, B. F. Thomas, C. C. Hutchins and F. C. Robinson, and a host of others who have made special study of the action of vacuum tubes.

Success in making sciagraphs depends very largely on a familiarity on the part of the operator with the action of the tube and the changes that may take place in it while undergoing bombardment.

Shape of the Tube.—It is now well known that the best tubes for producing efficient X-rays are those so constructed as to concentrate or focus the cathode rays either on a reflecting surface within the tube or a convenient spot on the wall of the tube itself.

The source of the X-rays is the point against which the

cathode rays are first projected. Whether this be the wall of the tube or some other surface within the tube. The cathode rays can be concentrated upon this point both by the shape of the cathode electrode and the shape of the vacuum. It is well, therefore, to give such convexity to the shape of the cathode as will focus the cathode rays at a desired point. Cathode terminals made of aluminum seem to work best, and since the material of the cathode is gradually worn away by the action, the size and thickness should be considerable. If it is designed to have the cathode rays first strike the wall of the tube and then create X-rays, the anode terminal may be of aluminum also and terminate in a point or in a ring; the latter is better since it does not heat so quickly. But if the anode terminal is to be used as the point of contact or impingement of the cathode rays and so generate the X-rays, then it is best to have it made of a sheet of platinum and set at such angle as will direct the X-rays to emerge at the spot on the the tube where the glass has been purposely blown thin. When the X-rays are once created their escape from the tube should be facilitated as much as possible, and this is best done by having the glass at the point of their exit blown as thin as is consistent with the safety of the tube.

A long narrow tube, therefore, with comparatively thick walls, but thinned opposite the point of impact or emergence of the X-rays appears to be the most efficient shape. The best work has been obtained from this, or from some form of "focus" tube. The length of the tube should be selected to correspond with the potential used. The higher the potential the longer the tube will need to be, and if a very high potential, as from a disruptive discharge coil, is used, it may be found necessary to limit the electro-static action created about the tube by immersing it in oil.

The Vacuum.—More seems to depend upon the electric potential employed than the degree of rarefaction within the tube, for even with comparatively low vacua X-rays are generated with high potentials. The vacuum increases very much during the action of the tube. This is thought by some due

to an actual propulsion of molecules through the walls of the tube, while others believe the walls absorb and retain the gaseous particles. When from action the vacuum grows so high as to impede the discharge through the tube, it can be readily reduced by gently heating the tube with the flame of a spirit lamp or Bunsen burner. The heating appears to set free the gaseous particles from the walls of the tube. The degree of vacuum suitable for generating X-rays bears direct relationship to the electric excitation and the best action of any tube can only be determined by experience with it.

Action in the Vacuum Tube.—This has been most graphically and accurately portrayed by Tesla. "When the Crookes phenomena show themselves most prominently there is a reddish streamer issuing from the electrode, which in the beginning covers the latter almost entirely. Up to this point the bulb practically does not affect the sensitive plate although the glass is very hot at the point of impact. Gradually the reddish streamer disappears, and just before it ceases to be visible the bulb begins to show better action, but still the effect upon the plate (or screen), is very weak. Presently a white or even bluish stream is observed, and after some time the glass on the bottom of the bulb gets a glossy appearance. The heat is still more intense and the phosphorescence through the entire bulb is extremely brilliant. One should think that such a bulb must be effective, but appearances are often deceitful, and the beautiful bulb still does not work. Even when the white or bluish stream ceases and the glass on the bottom is so hot as to be nearly melting, the effect on the plate is very weak. But at this stage there appears suddenly at the bottom of the tube a star-shaped changing design, as if the electrode would throw off drops of liquid. From this moment on the power of the bulb is increased ten-fold, and at this stage it must always be kept to give the best results."

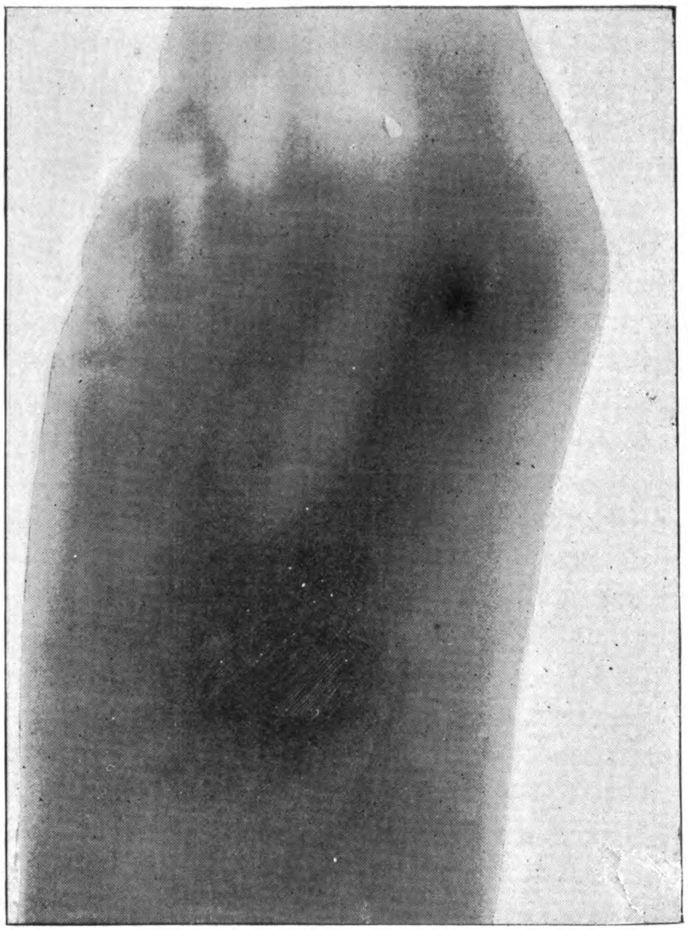


Figure IV.

Fluorescent Screens and Sensitized Plates.

The quality which certain substances possess of fluorescing when exposed to these invisible rays was not only the road to their discovery, but serves as a very ready means for detecting the presence and quantity of the rays. Röntgen made use of a fluorescing screen made of platino-cyanide of barium. Salvioni had none of this material at hand when he wished to construct what he has termed his *Cryptoscope*, but tried calcium sulphide which he found worked very well. He spread it on to the card-board end of a tube by means of fish-glue, while in the end of the tube near the eye he placed a lense which made the cardboard, phorphorescing under the influence of the X-rays, more distinctly visible. Following in this line of experiment Edison not only discovered a long series of substance which fluoresce under the influence of X rays, but he found among them tungstate of calcium to be by far the most efficient, and from these researches his *Fluoroscope* was developed which is now an indispensable aid to sciagraphy. A thin flim of fluorescing material placed in contact with the photographic plate greatly reduces the time of exposure in making a negative.

The fluoroscope does not take the place of the sensitized plate in diagnosis, for the shadows cast upon it are not so sharp and distinct as those formed on the photographic film, and it leaves no permanent record. Yet it serves as a rough and ready means for examination and is most helpful in determining the action of the tube and fixing upon the best time for an exposure of the plate.

Some months ago John Carbutt reported to the members of the Franklin Institute that he had succeeded in preparing dry plates which, for X-ray work, were so far superior to the plates suitable for photographic work with light, that he had by means of them greatly reduced the time of exposure. We have used none of these plates and have from no other source heard confirmation of this statement. So far the plates in general use are those furnished for ordinary work with light.

As a rule the best results are obtained from slow developers. Slow plates, those suitable for landscape work, seem to act quite as well or better than the quick plates. The use of a phosphorescent film, as tungstate of calcium or platino-cyanide of barium, placed in the holder in immediate contact with the plate reduces the exposure to seconds when without it a corresponding number of minutes would be required. The stronger the action within the tube, that is, the higher the electric potential employed, the sharper definition will the negative show. The use of a diaphragm of brass or lead placed near the tube, and thus cutting off cross-rays, greatly assists in getting clear definition, but this is not so essential with "focus" tubes as with those in which the rays proceed from a more extended surface.

It was among the original observations of Röntgen that the actinic effect of the X rays varies inversely as the square of the distance of the sensitive plate from the radiant source, and this has been confirmed by later investigators, although there are some, as Prof. Pupin, who seem to have reached a contrary conclusion. Nevertheless it is true that the distance from the tubes at which a successful X-ray negative can be made depends directly upon the intensity of the action within the tube and the abundance of rays produced.

Dr. Wm. J. Morton's Technique.

NEW YORK CITY, June 24th, 1896.

My Dear Dr. Herdman:

I use the static machine extensively for this work, but on the whole prefer the coil, as more convenient and quicker. Both will do excellent work when properly managed.

As regards the static machine, a six-plate (32 inch diameter each plate), works well. Larger machines would be better, but we have not got them; smaller do correspondingly less work.

I put the tube in the circuit, long since described by myself as that of the static induced current, *i.e.*, in the

circuit, between the external armatures of Leyden jars in connection with each prime conductor. I use quite small jars. As the vacuum rises, larger jars may be required, and here comes danger, for the tube may break down. But the very high vacua are not essential to a good-working X-ray, and if the tube rises to an impracticable vacuum it should be heated freely with a spirit lamp until, upon passing current through it, the first faint tinge of blue appears at the anode, generally behind it. Now, as the vacuum gradually improves with use, a point will be reached in the history of the tube where it is doing its best work. That point may be judged of by the length of the spark gap between the discharging rods.

But let no one think that they can get the X-ray without risk to their tubes. I always run 50 per cent. overload, and always expect a break-down. But it doesn't always come, and it is during such a race that the best work is done.

Two minutes, at eight inches exposure, will give a good picture of the hand. If a "focus" or reflecting tube is used, the definition is beautiful. At a certain exposure, rather under, even the interossic muscles will show.

W. H. Meadowcraft, Edison Decorative Lamp Works, Harrison, N. J., makes a very fine tube called the "Standard Tube." But many makers now make fine focus tubes.

The experimenter should develop his own pictures, in order to study his work as he goes. A weak negative intensified is, I find, often much more beautiful than a negative due to a longer X-ray exposure.

As to coil, I believe only in the direct current as a source in the primary of the coil. A six-inch spark is good, an eight to ten or twelve is better, but a four-inch also will serve fairly well. What has evoluted out of confusion in my experiments is a coil (I use a twelve-inch), direct current from the 110 volt main, a break wheel, 8 breaks and 6,000 revolutions per minute, and the usual condenser. The strength of current to be used is entirely controlled by the vacuum in the tube. If this is low, little current *can* be used; if it is high, much current *must* be used. But the operator can, within reasonable

limits, govern the situation. He must work with spirit lamp or bunsen burner in hand. (N. B.—Be careful to avoid ignition of the lamp by heating while current is passing.) Also with his fluoroscope as a guide. A moderate current, flowing steadily, will steadily raise the vacuum. Watch the rise by adjustment of the discharging rods. A strong current will cause the vacuum to fall and the tube to heat at the cathode.

The radiograph of the ununited fracture of one years' standing you refer to (Fig. V) was taken within half-inch board splints. The pins shown confined the bandages. It was taken with a coil, giving a four and one-half-inch spark and a focus tube. Time of exposure I have now forgotten—say from five to fifteen minutes.

This "time of exposure" business is a wrong way to look at X-ray work, for one often spends fifteen to twenty minutes taking a picture which is practically really taken by a very few minutes, or even few seconds, of those exceptionally brilliant moments all tubes have, for the vacuum in a tube never remains the same for half an hour—never, I believe, the same for one minute. I have taken an arm, wrist and hand in two seconds, but I took advantage of the two best seconds out of many more which I could get my tube to exhibit.

What I have written applies only to present appliances and present methods as I now use them. A different Crookes tube, that is to say, one whose vacuum was not on a sliding scale, would change the tenor of many of my remarks.

I have touched most lightly on the matter, my dear Doctor, but what I have said I say from experience. I have now X-rayed the entire body, even in heavy adults. The chest and trunk is easy, the hips the most difficult.

The X-ray is a most fascinating field of work, and every experimenter should be encouraged to go on with it. It is surely a revelation to the surgeon—it is a positive gain alike to him and to his patient.

Trusting you will pardon the haste and incompleteness of this letter, and wishing the BULLETIN and you every success, I am, Yours most sincerely,

WILLIAM J. MORTON.

Description of Illustrations.

The illustrations in this number of the BULLETIN have been selected with the view of exhibiting what we believe to be a fair sample of the degree of service which Röntgen rays can at the present stage of progress, render to diagnosis.

So far little of value has been done to aid diagnosis in abnormal conditions of any tissues of the body other than bone except to locate foreign substances in them. But experiments reported by many investigators show plainly that we will soon be able to rely upon this method of diagnosis to discover all abnormalities within the body that are capable of being revealed by differences of shading or density.

Figure I.—Is a sciagraph of the right-hand of the writer. About a year ago the middle finger was the seat of a subacute periostitis resulting from septicæmia which resulted in an eburnizing and thickening of the proximal and middle segments and an anchylosis of the phalangeal joints with a lateral displacement of the terminal phalanx. Massage and cathodal electrolysis had greatly improved the condition at the time the sciagraph was made and yet it serves to disclose to the eye the abnormalities fairly well. This picture was made by B. E. Thomas, Professor of Physics in the State University of Ohio. The apparatus used was a Ruhmkorff coil giving a six-inch spark, energized by five storage battery cells in series, a pear-shaped tube with aluminum electrodes, and a lead diaphragm within half an inch of the botton of the tube. The hand rested upon the photographic plate-holder and was eight inches from the bottom of the tube. Exposure, 20 minutes.

Prof. Thomas has been able to get even better definition in much shorter time by the use of "focus" tubes.

Figure II.—This is the work of Prof. Drayton C. Miller, of the Case School of Applied Sciences, Cleveland, who is an enthusiastic worker in this field of research and has made some admirable pictures. The various reproducing processes through which this illustration has passed have robbed it of yet appeared. The reproduction fails to do it justice. It can

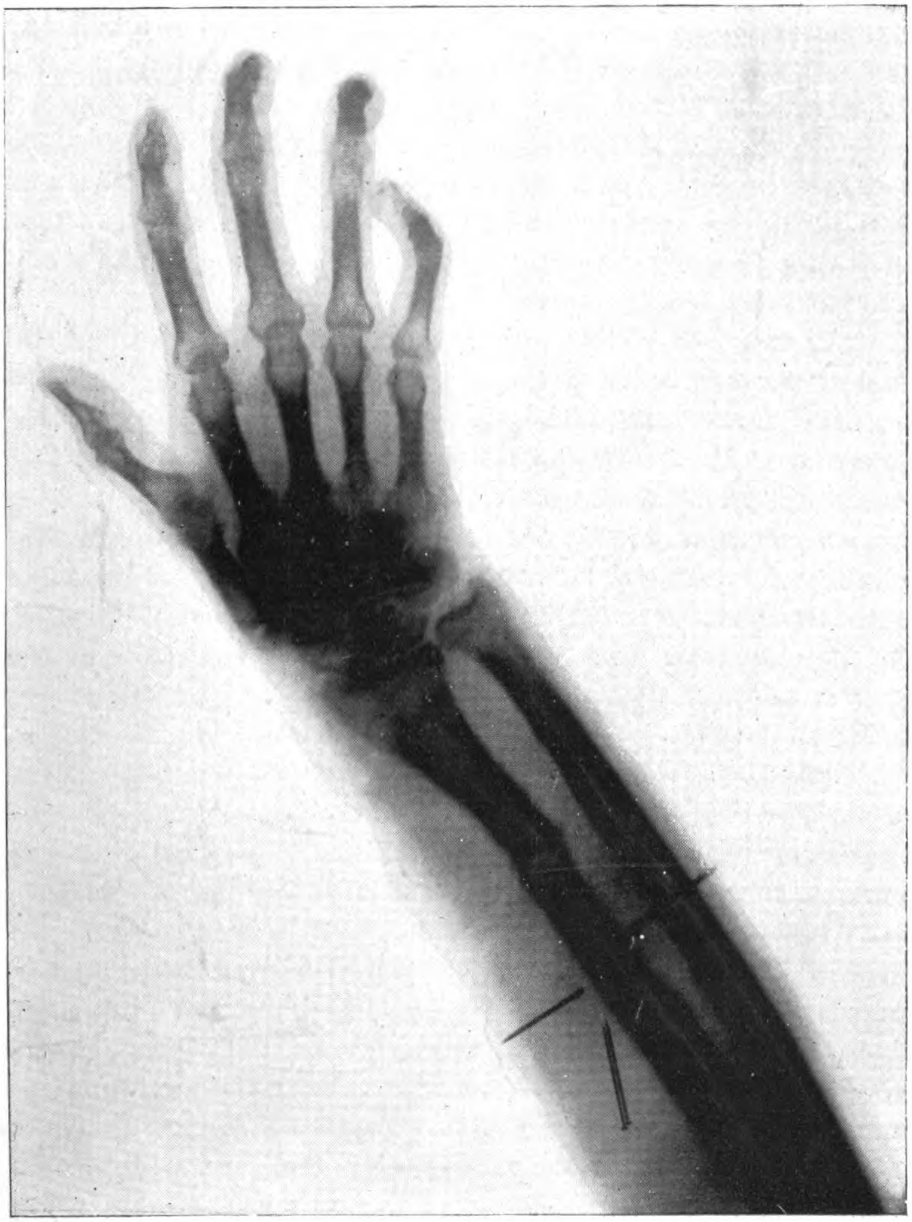


Figure V.

much of its original excellence. The subject is a forearm of which the ulna was for several years the seat of necrosis. Operations from time to time had removed portions of the bone and it now exhibits much shortening and an eroded appearance.

Figure III.—Is an illustration of the Edison Fluroscope manufactured by Aylsworth & Jackson, of Orange, N. J., and exhibits the manner of using it either for determining the action of a tube in generating X-rays or in examining shadow pictures cast on the fluorescent screen.

Figure IV.—Shows the location of a bullet in the distal end of the metatarsal bone of the great toe. The accident occurred to a young man in Detroit from the careless handling of a rifle. The irritation caused by the presence of the ball had resulted in great swelling of the foot, and cutting and probing by competent surgeons failed to locate it. The sciagraph was made at the physical laboratory of the University of Michigan with the assistance of H. S. Carhart, Professor of Physics. As the object was to get as good definition as possible of the lead in contrast with the tissues of the foot, no attempt was made to obtain a clear outline of the bones. The position of the ball in the transverse diameter is well shown, but when a second picture was undertaken with the view of locating the depth to which the ball had penetrated, the tube gave way under a current of too great potential, and there was none to take its place. The one picture, however, served to direct the incision through which the ball was removed and the foot saved. The appliances used were a Ruhmkorff coil giving a five-inch spark energized by storage cells, twelve to eighteen volts, the same tube as was used for making the picture of the hand (Fig. 1), and a brass diaphram with a half-inch aperture. The foot rested on the plate-holder and was about eight inches distant from the bottom of the tube. Exposure, thirty minutes.

Figure V.—This is the sciagraph to which Dr. Morton refers in his letter. The original was made on a large photographic plate and is one of the best pieces of work that has

be readily appreciated that a means for determining by sight the position of fractured bones, either before or after the attempt is made to reduce the fracture, is oftentimes of inestimable value to the surgeon. Dr. Morton has himself stated the conditions under which the original of this picture was taken. Samples of any of Dr. Morton's sciagraphs can be had by applying to Meyrowitz, 101 East 23 street, New York.

Notes.

Why the Röntgen Rays are Invisible.

X. Dariex and A. de Rochas, have made some experiments with the view of determining the degree of permeability by the Röntgen rays, of the transparent media of the eye —cornea, aqueous and vitreous humors and crystalline lens. The question was, do these media offer a geat resistance to the passage of the rays. It was noted that the index of refraction of the crystalline lens was 1.44 to 1.45 which is in the neighborhood of that of glass (1.52).

The authors made two series of experiments. In the first series, an eye was exposed for 20 minutes to a photographic plate wrapped in four sheets of black paper, the cornea being nearly in contact with the tube. The result was to show only a halo at the periphery of the plate, the eye acting like an opaque screen to intercept the rays.

Again, upon a similar plate, were placed one of the branches of a pair of scissors, a crystalline lens, a piece of muscle of the same thickness as the crystalline lens, a cornea and a small piece of wood. The crystalline lens was placed in the center of the ring of the branch of scissors, and in the axis of the tube, hence it received the X-rays directly. After 20 minutes exposure, the negative showed these results: The branch of scissors was very opaque, the crystalline lens was only slightly less opaque, the muscle was about the same as the crystalline lens, the cornea was somwhat less opaque while the wood was much less so than the cornea.

In the second series, it was desired to make a comparison, as to permeability by the X-rays, between the transparent media of the eye and other organic tissues, especially those of the hand.

The photographic plate was covered with 5 sheets of strong black paper and upon it was placed a fresh eye from the pig. From the eye the membranes—sclerotic, choroid and retina—were lifted away from the posterior pole for a distance of 8 to 10 millimetres, so that the X-rays might have to pass through nothing but the transpartent media, and the sensitive plate might serve as the retina.

The eye was thus prepared so that one might see through it as through a glass. It was then placed upon the photographic plate, within a triangle formed, upon two sides by the middle and ring fingers (the latter bearing a ring) and upon the third side by a rectangle of wood, This piece of wood was 1.50 centimetres high and served to keep the fingers apart.

The plate thus arranged was placed about 8 centimetres from the lower end of the tube, in such a manner that the eye was in the axis of the tube and received the maximum of the rays.

After an exposure of about half an hour, the negative showed that while the eye had been exposed more directly than the fingers to the rays, it appeared more opaque than the muscles and other tissues of the fingers but less opaque than the bones and especially than the gold ring.

Besides, a careful examination of the image of the ocular globe as it was projected upon the plate, showed in the center a still darker circle. This indicated without doubt a greater opacity of the central portion of the eye, precisely the portion which is transparent for our vision.

From these observations, the authors conclude that the transparent media of the eye which let the rays of light pass through them so perfectly and instantaneously; are very slightly permeable by the X-rays.—*Revue Scientifique*, Feb. 29, 1896.

VOLUME III. OCTOBER, 1896. NUMBER 4.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN.

Published Quarterly by The Inland Press, Ann Arbor, Mich.
Subscription Price, One Dollar a Year.

Static Machines for Therapeutic Work.

Static, or frictional electricity is the form in which this agent was first brought to the intelligent attention of mankind and by which, therefore, it has been longest known. The physiological effects of the static spark derived from the crude apparatus of Von Guericke of Magdenburg, as early as the middle of the seventeenth century, aroused curiosity, attracted attention, stimulated investigation, and was the means of directing the thought of physicians to electricity as a therapeutic resource. But the machinery for generating static or frictional electricity had to go through many successive stages of experiment before it furnished an instrument that could be relied on for therapeutic work.

The invention of influence machines by Holtz and by Töpler in 1865 met this want, and these with the later invention of the Wimshurst machine now amply supply us with instruments for dealing with such abnormal conditions as can be successfully combatted by means of static electricity.

In the Holtz machine the original or primary charge must be supplied to the machine, and this under suitable conditions is multiplied by induction as the movable plates are rotated. When at rest, however, and when the atmosphere is warm and humid, this machine readily loses its charge and is at times recharged with much difficulty. The Töpler and Wimshurst machines are self exciting. This feature in their action is obtained through augmenting the slight difference of potential that usually exists by means of metal buttons, more or less in number, attached at regular intervals to the surface of the revolving plates and projecting so as to come in contact with metallic brushes of tinsel or fine wire fixed on the ends of metal rods. The friction caused by some of these brushes, augments the initial charge while others of them serve the purpose of discharging by contact the electricity accumulated on that part of the plate which passes them. The presence of these brushes, buttons and metal inductors on the Töpler and Wimshurst machines are somewhat of a detriment to their insulation, and in this respect render them inferior to the Holtz, of the same size, in the amount of electric energy produced. But the conditions which furnish the initial charge by friction in the former machines are constant while they are in motion, each revolution adding its increment of difference of potential from this source, which renews the supply of electricity and makes the generating capacity of these machines more constant and reliable.

The manufacturers of the Holtz machine for medical use have of late years furnished it with a small Wimshurst for the purpose of exciting action in the Holtz when it loses its charge, and the latest improved static machine of the Holtz variety has a small Wimshurst included in the case with it, so arranged that a charge from the small machine can be readily transferred to the plates of the larger one.

The Wimshurst machine is especially reliable in creating a difference of potential and in getting into action because its construction is such as to give a large amount of friction between the metallic brushes on the stationary plates and

the carriers on the revolving plates. These metal carriers or sectors are greater in number than on the Töpler machine and the arrangement which causes the revolving plates to move

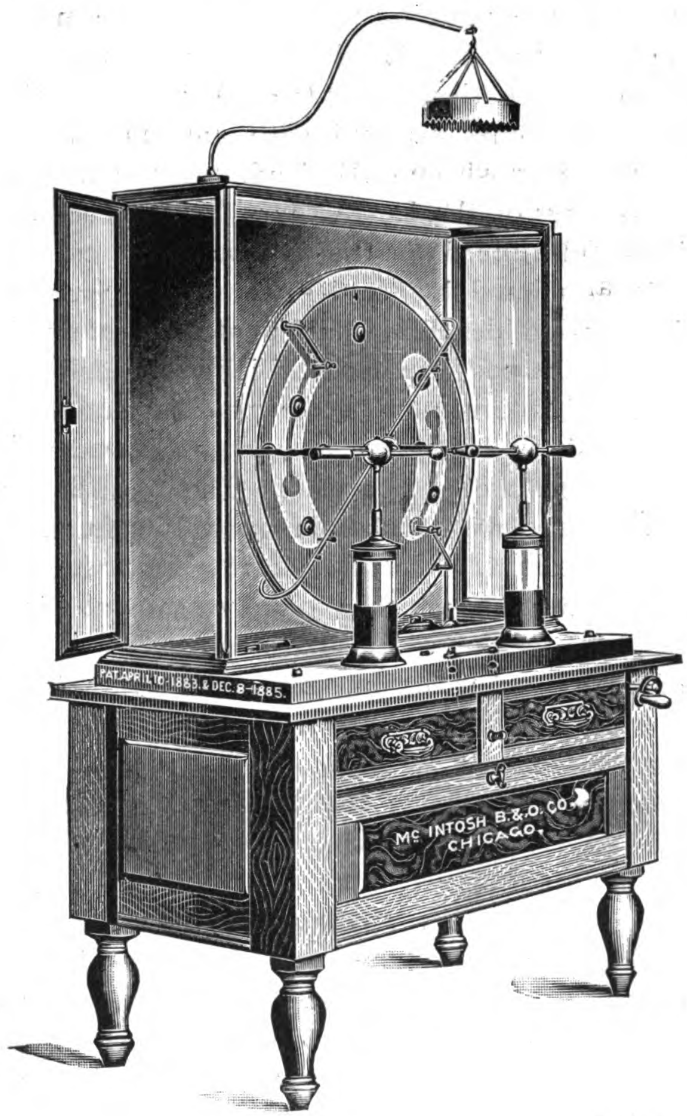


FIG. I. ATKINSON-TÖPLER MACHINE.

in opposite directions favors a rapid development of the charge. The mechanism of the Wimshurst is not, however, well adapted to secure durability in a machine of large size, so that

they are not so well suited for developing quantity of electricity as either the Holtz or Töpler form.

All static machines for therapeutic work are now provided with Leyden jars as condensers, so as to increase the quantity of electricity in the resulting spark. When the machine is in action the interior of one Leyden jar becomes charged positively, the other negatively, and the outer coating of each jar by induction becomes charged with an equal but opposite potential from that within. By leading off conductors from the outer coatings of the Leyden jars, an induced current can be obtained and utilized for therapeutic purposes. This current has been named by its discoverer the "static induced current" and resembles somewhat in nature the current derived from the fine wire coil of a medical induction coil, as it is an alternating, and interrupted current, but its potential is very high, the E. M. F. being far in excess of that which any medical induction coil can furnish. The frequency of interruptions of this current depends upon the frequency with which discharges take place between the interior armatures of the Leyden jars at the spark gap which separates the prime conductors, and as the width of this spark gap is under the control of the operator the number of interruptions and the strength of the "static induced" current can be varied at will.

The resistance which the static machine is able to overcome at the instant a spark crosses the air gap between the prime conductors shows us that we are here dealing with electricity in a state of very high potential. The E. M. F. of the direct currents which we have heretofore considered as adequate for electro-therapeutic work is entirely inadequate to carry a current across the resistance of the minutest air gap. And the most powerful medical induction coil now in use gives an E. M. F. capable of forcing a passage through but an infinitesimal film of air resistance. But well constructed static machines of fair size will readily develop an E. M. F. that will cause the current to leap an air gap between the prime conductors of eight or ten inches (20 to 25 cm). The E. M. F. required to overcome the resistance offered by such a

large interval of dry air is enormous. Although no careful measurements of the E. M. F. of the static machine are yet recorded, a rough estimate can be made from the size of the air gap traversed by the current as shown by the spark.

A spark 1 mm. in length would indicate an E. M. F. of

at least	2,000 volts;
One of 1 cm..................	10,000 volts;
One of 10 cm................	100,000 volts;
One of 25 cm................	1,000,000 volts

approximately.

But while the voltage is extremely high the current actually passing is exceedingly small, seldom more than the fraction of a milliampere.

The spark is the result of a sudden breaking down of the dielectric; that is, the air stratum between the prime conductors. "The difference of potential has so far increased by the working of the machine that the air stratum no longer offers sufficient resistance; it is in a state of gradually increasing strain and finally gives way and a discharge of electricity takes place equalizing the potential. The spark is not itself electricity, but is due to the heat and light generated in the intervening particles of matter as a consequence of the mechanical violence of the disruption. The discharge which causes the spark is apparently unidirectional but in reality it is oscillatory in character, the rapidity of the oscillations occurring with marvelous frequency and gradually decreasing amplitude." The vibrations of one discharge may reach as high as a hundred million or more per second.

The difference of potential which is created by the action of the static machine seeks relief from the strain produced on the surrounding insulators or dielectrics in other ways than through the sudden disruption which causes the spark discharge. Foreign substances suspended in the atmosphere as dust, or watery vapor as well as the air particles themselves, become charged with electricity of different potentials and are repelled from and attracted to different parts of the apparatus, according to their polarity. A stream of such particles may produce

an actual current in the air if escaping from some point or edge where high degree of difference of potential is maintained. This is what constitutes the so-called "electric breeze" and if it is accompanied by noise and light it is termed a "brush discharge."

It is sometimes desirable to know, when using a static machine in therapeutic work, which prime conductor has positive and which negative potential. The position of the prime conductor or Leyden jar will not serve to designate the potential since in the action of the machine the potential may become reversed. The most satisfactory method for determining which conductor is positive and which is negative is to observe the machine while in action in the dark, when the positive side can be recognized by the tips of the collecting comb showing points of light while upon the opposite or negative side the light appears in brush-like form.

In order that a static machine may be kept up to its highest efficiency care must be taken to preserve intact the conditions essential to its action. Dust or moisture upon the plates rapidly equalizes the difference in potential created. Variations in the amount of moisture in the atmosphere affect the working of the machine. It is best, therefore, to have the plates of the machine enclosed in a case where they can be kept free from dust and where if necessary the air can be subjected to artificial methods of drying, either by means of a dish containing petroleum or anhydrous calcium chloride placed within the case. All unnecessary points and projections should be avoided in the construction of the machine since they serve to dissipate the electric energy produced.

The increase in the size and number of the plates increases the quantity of electricity, but there is a point beyond which such increase possesses no additional therapeutic advantages. The prevalent opinion at present among those experienced in the use of static electricity in therapeutics is that a machine having eight plates, four revolving and four stationary, the revolving plates being from 28 to 36 inches diameter, is capable of doing all that is at present sought for from a machine of this kind.

Physiological and Therapeutic Action of Static Electricity.

We have considered the structure and action of static machines for therapeutic work and the physical properties of the electric energy which they produce. It remains for us to study the behavior of the human organism in health and disease when subjected to electric conditions such as the static machine and its accessories can furnish.

The extremely high electro-motive force of electricity when generated by the static machine renders it prone to break down the dielectric which surrounds all conductors and other bodies charged with it and so escape. The dielectrics or insulators that are employed in the operation of the static electric machines which physicians use are the glass plates of the machine itself, the glass of the Leyden jars or condensers, the glass or hard rubber used for the various supports of the conducting parts of the machine as well as for the feet of the insulating stool, and lastly, the air which surrounds all parts of the machine and the objects in continuity with its conductors. In order that a body may be subjected to a high degree of static charge these various dielectrics must be capable of sustaining considerable strain without giving out, that is, there must be a sufficiently thick layer of air or glass or hard rubber separating from surrounding objects the bodies and conductors which the machine has brought to a positive potential so as to prevent the charge from escaping to the earth through some object which is in connection with it, and may serve as a conductor. Particles of moisture or dust in the atmosphere which surrounds the machine aid in dissipating the charge which the machine creates, and for this reason a dry atmosphere and one free from dust is an essential if a static machine is to do its most successful work.

The physical conditions created by means of static machines that are employed in therapeutics may be enumerated as follows:

Static insulation,
The direct spark,
The indirect spark,
The friction spark,
The spray or breeze,
The needle spray,
The static induced current.

Static Insulation or Charge.—A patient to be subjected to this condition sits upon the insulated stool or platform, which is attached to one or other, usually the positive, pole of the machine by means of a conducting chain or rod. When the machine is put in motion the body of the patient, thus forming the terminal of the conductor, is raised to such a potential as the machine is capable of producing, and the patient becomes the storehouse of a positive or negative charge, depending in amount upon his or her electrical capacity. Just here there is need of some careful study in the comparative effects of positive and negative insulation. It is very generally agreed among those who have employed this form of treatment that it is followed by marked nutritional effects, yet some claim that positive insulation is stimulating and beneficial, and negative insulation is depressing and hurtful, while others assert that there is no such noticeable difference in effects between them, but that either form of insulation will prove tonic and invigorating. Only a carefully arranged series of tests faithfully carried out in both the domain of physiology and therapeutics can satisfactorily settle this mooted question. It is claimed for static insulation, and as commonly employed this means positive insulation, that it will elevate a subnormal temperature, or lower a temperature abnormally high; that it will regulate and increase the volume of the pulse; that it will decrease the number but increase the depth of respirations; that to a person nervously excited and sensitive, it imparts a sedative effect and a sense of well being. The action appears to be to improve nutrition and regulate disordered function, although the manner in which a static insulation or bath operates to produce this effect has not yet been explained.

The Direct Spark (*Fig. 2*).—In giving the direct spark, the patient is placed upon the insulating platform (F), which is connected by the chain or rod to either the positive (B) or negative pole of the machine, and the first effect upon the patient (P) is to produce a static charge of either positive or negative potential, as the case may be. Here again the positive charge for the patient is ordinarily used and preferred. An electrode (H) terminating in a metal or gilded ball about two inches in diameter is attached to the other pole of the machine (B^1). When this electrode is made to approach the body of the patient at any point, the layer of air which surrounds the patient and acts as a dielectric is thereby rendered

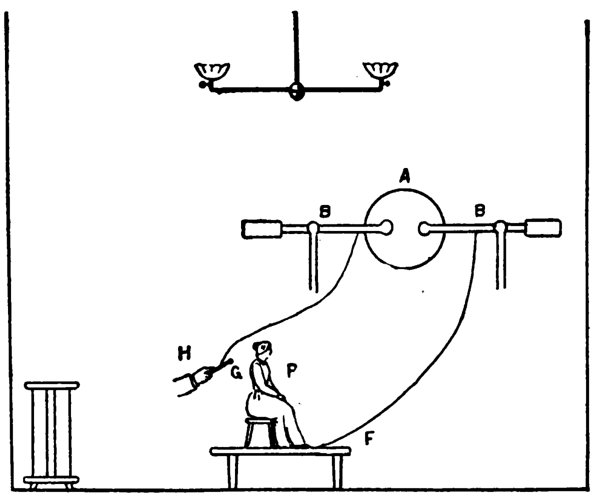


FIG. 2.

thinner (G), and less capable of sustaining the strain to which it is subjected, and finally it is so thinned by the nearer approach of the ball electrode that it gives way and the static charge in the patient's body suddenly becomes transformed to current electricity and escapes, leaping the air space in its transit and causing a spark.

The physical phenomena here are the sudden dissipation of a static charge which had been maintained in the charged body at a very high potential. The discharge is often if not always oscillatory in character, the oscillations numbering many thousands per second. The current by reason of the

extremely high resistance to be overcome at several points in the circuit, is very small, usually but a fraction of a milliampere. The human organism, which is for us the point in the circuit of greatest interest, is suddenly subjected during a treatment of this nature to a high electric potential, which it as suddenly loses as often as the ball electrode is brought sufficiently near to some part of the body to cause sparking. As all parts of a charged body are at a uniform potential a change must take place throughout the entire organism when the potential is reduced to zero, as is the case when a spark crosses the air gap, and if this discharge is not instantaneous in its decline of potential but oscillatory, with gradually decreasing amplitude of oscillations, the organism must be subjected to corresponding disturbances in its molecular arrangement throughout. The tissues of the human body are not uniform in conductive capacity, consequently the density of the charge is not uniform throughout the entire organism. Both during charge and discharge therefore, the human body must be supposed to act quite differently from a mass of metal of equal size and form under similar electric conditions. Certain of the tissues conduct readily while others possess the characters of dielectrics. There would therefore, be innumerable spots of strain and slip in close relation which must be taken into account when we attempt to analyze the effects produced during a static treatment. But whatever may be the fact as to the spark discharge causing molecular excitation of the entire organism, a series of phenomena capable of ocular demonstration always occurs at that part of the body where the discharge takes place. There is a sudden blanching of the skin, due to vaso-motor constriction over a circular spot greater or less in diameter, according to the strength of the discharge; this is soon followed by a vaso-motor dilatation and the spot is correspondingly reddened, a condition which remains for a considerable length of time after the treatment. The muscles underlying the point from which the discharge takes place are caused to contract and sensations of a variable nature, referred to the same spot, are prominent accompani-

ments. These sensations are an important element in the treatments for upon their nature often depends the good or bad effect which the patient experiences. The direct spark from small machines is much more likely to be stinging, pricking and irritating than from large machines, and it is claimed that grounding the machine has the effect to render the spark much less disagreeable than when the circuit is confined to the machine, the conductors and the patient, as is the case when using the direct spark. The static spark is of great value in arousing to more active nutrition any organ of the body that is subjected to this treatment. The skin, the vascular tissues, muscles and nerves are stimulated by it. Its effects are more generally distributed throughout the body than is the case with the direct or induced current applications, so that it is well suited for correction of systemic disorders, such as rheumatism, gout, neurasthenia, spinal irritation and general sluggishness in nutrition from whatever cause. Unmistakable evidence is given of its power to quicken nutritive processes by the way in which the perspiratory and sebaceous glands are set to work by it, and the improved bodily comfort that follows such applications, is due in a great measure, no doubt, to the more perfect elimination of effete matters from the body.

It is sometimes difficult to give the spark treatment to special localities of the body by means of the ordinary ball electrode for the reason that the current which causes the spark invariably seeks the line of least resistance. A directive electrode, such as the Morton Electrode is of much service in getting exact local effects, and by means of the spark can be drawn trom accessible surfaces within the cavities of the body when this is thought desirable.

The Indirect Spark (*Fig. 3.*)—In order to get the indirect spark the machine must be "grounded." This is done by putting the negative prime conductor or pole of the machine in communication with the earth by means of a conductor running from it to a convenient gas-pipe or water-pipe. The electrode used for the purpose of drawing sparks should also be

grounded. This has the effect of increasing the quantity of electricity which the machine generates and improving the constancy of its action. The spark is likely to have more volume and is cleaner, with less irritating properties. It is more satisfactory, therefore, when using the spark treatment to have the machine grounded. A sputtering series of sparks is very disagreeable to most patients and irritates the sensory nerves and should always be avoided except when this effect is sought for, as is the case when counter-irritation or skin excitation is desired. It insures a clean, full, individual spark

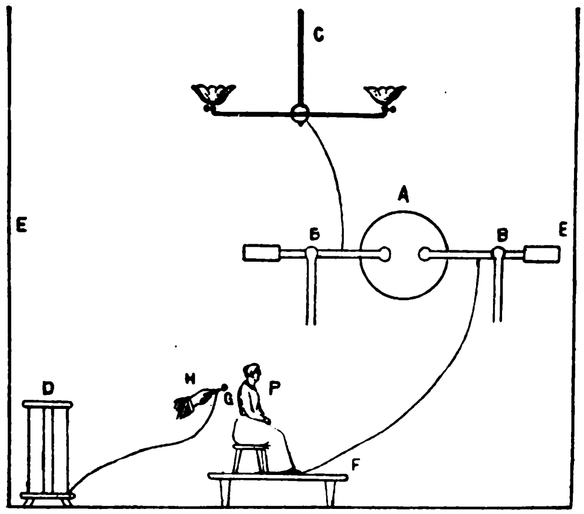


FIG. 3.

to have the machine well grounded and then make the ball electrode approach the part of the charged body suddenly to within the proper distance and as suddenly withdraw it.

The purpose and manner of the treatment with the indirect spark is the same as that with the direct spark, but the effect differs because of the physical and physiological differences which they possess.

The Friction Spark.—This is used mainly for excitation of the skin or the superficial blood vessels and is a convenient method for applying mild counter irritation. The patient is insulated as with the spark treatment. A roller electrode is provided for this application but is not necessary since the large ball electrode will serve the same purpose. The

only physical difference between this and the direct or indirect spark is that the dielectric is thinned down to a layer which is represented by the thickness of the patient's clothing. The roller or ball is passed over the spot treated directly in contact with the clothing, consequently the charge escapes at more frequent intervals and with smaller sparks but with a prickling, biting or stinging effect upon the sensory nerves of the skin which is decidedly exciting to their function and the reflex effect upon the nutrition of the skin is marked.

This form of treatment is of special service in correcting chronic malnutrition of the skin as in eczema and sensory paresis.

The Spray or Breeze.—Again the patient is insulated as before but the charge is withdrawn, not suddenly, as in the forms of treatment thus far mentioned; but slowly and in infinitesimal quantity by holding a pointed electrode at such distance from the part of the body to be treated that the discharge is not disruptive but is conveyed away by the particles of air forming the dielectric layer, each becoming charged with its load and seeking the opposite potential. This creates a current in the atmosphere surrounding the part of the patient's body under treatment. This motion together with the gentle stimulating effect caused by the slight loss of potential in the surface which each instant takes place by the process of convection that is going on, constitutes the treatment.

The pointed electrode may be moved about over the patient's body. Or, by fixing it upon a stand, it can be so placed that the effect may be maintained for any desired length of time upon a particular part. A circle of points fixed at a suitable distance above the patient serves to distribute the "spray" or "breeze" uniformly over the head.

The static spray or breeze is peculiarly soothing and resting in its effects. By means of it a condition of nervous excitement and restlessness can be almost immediately allayed. Severe headaches of a nervous type are often quickly relieved and insomnia is frequently overcome.

The Needle Spray.—When only a part of the patient's body is brought in the direct line of charge, and so is raised to a higher potential, as would be the case if the conducting chain is held in the patient's hand instead of being placed on the insulating stool, and the pointed electrode is then brought near enough to the part to be treated to allow of minute disruptive drops of potential instead of the discharge by convection, the effect upon the part under treatment is much as if it was being pricked by innumerable fine needles. This is decidedly stimulating, though at the same time irritating, and is in all respects of the same nature and used for the same purpose as the friction spark above described.

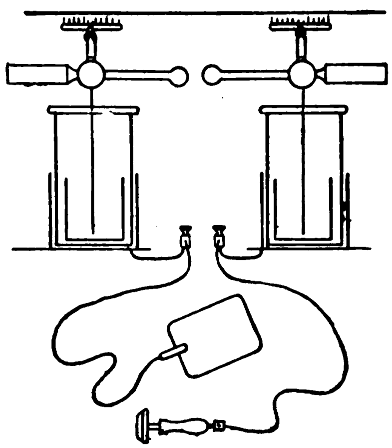


FIG. 4.

The Static Induced Current.—We are indebted to Dr. W. J. Morton, of New York, for bringing to our attention this very valuable addition to the therapeutic resources furnished by the static machine.

The static induced current is that current which results from a return to zero of the difference of potential that is created between the outer coatings of the Leyden jars or condensers attached to the prime conductors of the machine (Fig. 4). At each instant that a discharge takes place between the prime conductors, the potential difference which existed in the interior of the Leyden jars is equalized and a corresponding discharge takes place between the exterior sur-

face of these jars and this latter current can be utilized for therapeutic applications without the disagreeable accompaniment of sparks. The electrode for applying this current can also be placed in contact with the body and the various tissues and organs be brought under its influence with more precision than is possible in the use of the spark or spray. All modern static machines designed for therapeutic work are furnished with connections that permit the use of the static induced current. For the regulation of this current it is only necessary to regulate the discharge between the prime conductors of the machine. A small spark-gap permitting frequent minute discharges will be attended by a similar frequency and feebleness in the static induced impulses. A wider separation of the prime conductors will result in heavier discharges at longer intervals. The strength and frequency of the impulses of the static induced current is thus readily controlled. The nature of this induced current is similar in potential to that of the inducing current. The milliamperage depends upon the resistance offered in the circuit. It is in all probability, at times at least, oscillatory in character, although this remains to be determined with certainty. As to the physiological effects and the therapeutic applications of the static induced current we will quote the words of Dr. Morton himself whose rich experience in the use of this current will give to his conclusions the weight of authority.

"Applied to a motor point, the static induced current produces most vivid and persistent muscular contraction with a minimum of pain; applied farther back on the trunk of a motor nerve it throws large groups of muscles into contraction. The contraction is peculiarly painless as compared with that of faradic coils, and the influence is remarkably diffusive. Accompanying a contraction of a large group of muscles is a peculiar sensation of lightness and buoyancy of the member. The painlessness, diffusiveness, and buoyancy may all be experienced by holding the two electrodes in the hands, and taking a current as strong as possible. Most people will readily submit to flexions successively at the wrists, elbows,

and even to the shoulders before insisting upon taking no more. The arms during the passage of the current feel as if made of cork, and this feeling of lightness persists for some time. It is the same feeling, doubtless, though here exaggerated, as is commonly referred to as the refreshing effect of general electrization. The quality of the current is such, that while energetically exciting the motor function of the nerve filaments, it fails to excite or may even annul, to an extent, the sensation of muscular pain. Its penetrating, diffusive, painless effect, with strong muscular contractions, adapt it admirably to general application over the entire body as an electric in place of an ordinary massage.

"It is, of course, applicable to every form of muscular paralysis, for there is no practical stimulus to nerve and muscle except the electric, and none more energetic than this form of it.

"Its effects upon the Hallerian irritability of the muscular tissue necessarily includes an effect upon the local circulation of a part and upon the lymphatics, and to this may doubless be referred many clinical results of relief, as in lumbago and all forms of muscular rheumatism, subacute and chronic rheumatic affections of the joints, ovarian or pelvic pain, sciatica or other neuralgias.

"The second prominent characteristic of this current is its power of relieving pain. Leaving out of sight the part, be it more or less, played by circulatory changes referred to, in this respect there seems to exist a specific analgesic quality in the current. The cotton feeling in the hands and subjective sense of buoyancy in the arms is in itself an evidence of this. But the effect upon pelvic pain, upon ovaritis, upon neuralgias, pleuritic 'stitches,' tonsillitis, and many other pain affections is still better evidence. In sciatica, for instance, the sensation of pain is frequently quickly relieved and a cure obtained, though I think in this case the cause is twofold—that is to say, due to both the circulatory and the analgesic effect. The same I believe to be true in the pelvic and ovarian pains.

"The results in such cases, in my opinion, are far superior to anything obtainable by a faradic or a galvanic application. An ordinary faradic current will increase the pain; the galvanic will very often relieve it. But we have in the static induced current no comparison to the electrotonic and polar effects, or in general the electrolytic effects of the direct or galvanic current. Therefore, when the static induced current has failed to act favorably, we should try the galvanic, and *vice versa*. As no observations on the purely analgesic effects of this current have hitherto been made, I must leave others to test the question for themselves."

It will be seen from this brief review of the methods of practical application of the effects obtained by means of the static machine that it is capable of doing a variety of work in therapeutics which no other form of electrical apparatus can accomplish; but the good results obtainable can only follow when the action of the machine is fully understood by the operator and the case to be treated is one adapted to the form of treatment employed.

The Static Machine for Röntgen Ray Work.

Excellent results can be obtained from the use of the static machine for exciting the Crookes' tubes to produce X rays. Even small machines of the Wimshurst, Toepler, or Atkinson-Toepler pattern can be made to do good work in the production of X rays, but the best results are secured by using the larger machines, those of six or eight plates of large diameter. The tubes used with the static machine should be especially constructed for its capacity. If the experienced manufacturer of Crookes' tubes is informed as to the form and size of the static machine and its sparking capacity, he can make a selection of tube in size, shape and degree of vacuum that is best adapted for it.

When a static machine is used for generating X rays it is most convenient to have it revolved by means of a water or electric motor the speed of which can be regulated at will.

The manner of connecting the tube to the conductors of the machine is a matter of prime importance for getting the best effects. Some action may be excited in the tube by connecting the terminals of the tube directly to the prime conductors or by putting it in the "static induced" circuit, but we have uniformly obtained the greatest out-put of Röntgen rays by making the connections as shown in the accompanying diagram (Fig. 5). The only additional attachment to the machine for this purpose is the upright standard to which one of the connecting wires is attached. The lower portion of this is made of wood or hard rubber; the upper portion is a brass

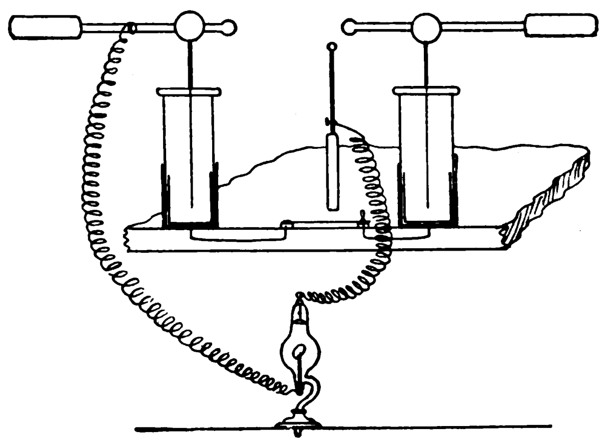


FIG. 5.

rod tipped with a small brass ball. It can be made to fit into a socket in the wooden base of the machine or can have its own base and is thus readily removed when the machine is used for other than X ray work.

The length of the spark-gap can be conveniently regulated by moving back and forth one of the prime conductors in relation to this standard, while the other prime conductor should be withdrawn to the full extent. The size of the condenser used needs to be adapted to the capacity of the tube. Usually very small condensers give the best results, but a change in the condenser capacity is not infrequently just what is needed to secure the desired action in a tube.

Up to the present time we have found in this laboratory a reliable static machine of sufficient capacity, run by a motor,

and provided with the standard above mentioned and with arrangement for varying the condenser capacity the most convenient and most satisfactory apparatus for furnishing X rays.

Notes.

We have frequent inquiries from physicians and others regarding books relating to electricity and electro-therapeutics. If we were able to answer these inquiries by recommending any one text-book among the many which have undertaken to treat of electricity as applied to medical and surgical practice the work in which this laboratory is now engaged would be superfluous.

Such rapid advances have recently been made in our knowledge of electricity and its relation to the living organism that no one book nor combination of books furnish answers to all the questions that are constantly presenting themselves. Laboratory research and experiment and clinical experience can alone do this, but we venture to publish below a list of a few books that our experience has found to be helpful to those who are interested in and desire to still further perfect themselves in electro-therapeutics:

Electro-Physics.

Dynamic Electricity. Philip Atkinson. Published by Van Ostrand Co., New York.

Electricity and Magnetism. Lessons of the National School of Electricity, Chicago.

Electricity in Electro-Therapeuttcs. Houston & Kennelly. Published by W. J. Johnston, New York.

Ruhmkorff Coils. H. S. Norrie. Published by Spon & Chamberlain, New York.

Elements of Static Electricity. Philip Atkinson. Published by Van Nostrand Co., New York.

The X Ray. Wm. J. Morton and Edwin Hammer. American Technical Book Co., New York.

Electro-Therapeutics.

An International System of Electro-Therapeutics. Horatio Bigelow. F. A. Davis Co., Philadelphia.

Electro-Therapeutics. Wm. Erb. Von Ziemssen's Hand-book of General Therapeutics. Publishers, Smith, Elder & Co., London, England.

Medical and Surgical Electricity. A. D. Rockwell. Wm. Wood & Co.

Technique d'Electrothérapie. Gautier & Larat. Edited by Maloine, Paris.

The Practical Application of Electricity in Medicine and Surgery. Liebig and Rohé F. A. Davis Co., Philadelphia.

Electricity in Diseases of Women. G. Betton Massey. F. A. Davis, Philadelphia.

Electricity in Facial Blemishes. Plym S. Hayes. W. D. Keener, Chicago.

Electro-Therapeutical Practice. Chas. S. Neiswanger, Chicago.

Journals.

Bulletin of the Laboratory of Electro-Therapeutics. University of Michigan.

Archives d'Électricité Medicale. Edited by Octave Doin, Paris.

Revue Internationale d'Électrotherapie. Gautier & Larat, Paris.

The Journal of Electro-Therapeutics. Wm. H. King, New York.

VOLUME IV. JANUARY, 1897. NUMBER 1.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN.

Published Quarterly by The Inland Press, Ann Arbor, Mich.
Subscription Price, One Dollar a Year.

Electricity in Dentistry.

Dentistry should be regarded, if it is not, as one of the specialties in the practice of medicine and surgery. The best Schools of Dentistry do so regard it and the curriculum of these schools provides for a fundamental training such as is required of the medical student. A thorough knowledge of chemistry, anatomy, physiology, hygiene, bacteriology, histology, pathology and materia medica is quite as necessary for the efficient practice of dentistry as of medicine and surgery. The field of operation for the dentist, though limited, is not any more so than that of the laryngologist, rhinologist, oculist or aurist. The variety of pathological conditions the dentist has to meet and contend with is quite as great as in any one of these other specialties and the resources he should have at his command, in order to successfully check and counteract disease in his peculiar field, are much the same. Especially is he in need of the help electricity furnishes, for not only can he get valuable aid from it as a motive power for various mechanical devices which are

peculiar to dentistry and for which electric motors are best adapted, such as drills, burrs, burnishers, mallets, etc., but, as a source of light for exploring the mouth, and of heat, when this is wanted for strictly limited application, electric means are far superior to any other.

But little need be said in these columns calling the dentists' attention to the advantages to be gained from using electricity as a substitute for driving motors or for furnishing heat for cauteries or the hot-air syringe or lighting exploring lamps, since the manufacturers of such appliances can be trusted to bring the merits of such devices to the attention of their customers and use will soon settle the question of superiority.

It is to the more strictly therapeutic applications of electricity to dentistry that we would direct the attention of the readers of the BULLETIN in the present number. Many inquiries have, from time to time, been addressed to us upon this subject. The demand for such knowledge, we find, is great and the sources of information limited.

Among the various forms of electric energy that have been considered in more or less detail in former numbers of the BULLETIN, i. e. the direct current or galvanism, the induced current or faradism, and static electricity, the former of these, the direct current, is the one to be chiefly if not solely considered, since it is the one most capable of effecting certain desirable changes in those tissues with which the dentist has to deal.

The induced current or faradism may be of some service in allaying pain or obtunding sensitive dentine or in stimulating nutritive activity in the pulp, gums or alveoli while the direct or galvanic current can not only do this but, in addition, its range of electrolytic and cataphoric action gives to it a much wider field of usefulness with which the dentist should become familiar. We will endeavor in the following articles to point out some of the applications of the direct current to dentistry.

Electrolysis in Dentistry.

While treating of Electrolysis in No. 2, Vol. I, of the BULLETIN, attention was called to the difference of effect upon living tissues produced at the anode or positive electrode from that at the cathode or negative electrode when a constant or direct current of even a few milliamperes is passed for a few minutes.

The fluids of the tissues and the substances in solution in them are decomposed. Oxygen, the acids and bromine, chlorine, iodine, etc., accumulate in the vicinity of the anode, while hydrogen, the alkalies and metals gather at the cathode.

It is possible then for the dentist, as it is for the physician, to utilize this capacity of an electric current, and to so localize its action upon any point with such precision as to increase the acidity or alkalinity of the tissue at that point, according to the pole used.

By this method of modifying the distribution of the constituents of the tissues nutrition may be changed for better or for worse, and the electrolytic action may be carried to such a degree at either electrode as to bring about extensive destruction of tissue.

Sometimes it is such destruction of tissue that the dentist desires. When that tissue is an abnormal growth, having its origin from any one of the tissues of the jaw, as a myeloma, no simpler or more efficient means can be employed for its removal than that of electrolysis. A strong needle may be introduced into the base of such a growth at the line where the normal tissue verges upon the abnormal, and such needle be made the positive electrode of a direct or galvanic current, of a strength of five or eight milliamperes. This will in a few moments of application produce such change in the vicinity of the needle as to check the further development of the growth at that point, and if the needle is applied at several points about the margin of the growth during the one treatment, and the process, if necessary, be repeated a few times the growth will undergo retrograde changes and disappear.

All kinds of abnormal growths that occur in the region of the mouth, no matter what their structure, are amenable to this disintegrating action of electrolysis and by means of it their removal can be effected with the least possible loss of normal tissue, for with suitable appliances and skill in handling them the destructive electrolytic action can be limited with the utmost nicety to the abnormal tissue only.

For such abnormal growths as are soft and vascular in structure the styptic, coagulating action of the anode is best adapted, while for hyperostoses, fibrous or cartilaginous overgrowth cathodal electrolysis, which causes softening and liquefaction, would be more suitable and be followed by resolution more promptly.

The strength of current that will effect these electrolytic changes in tissue is not great. A current of three or five milliamperes continued for five or eight minutes where the active electrode is a needle point, will so far devitalize the tissue in the immediate vicinity of the needle as to result in gradual disintegration and absorption at that point. A stronger current will result in immediate destruction of tissue, which will give a more noticeable change at the time of operation, but the result may be an extensive slough with a resulting sore and subsequent eschar which is oftentimes undesirable. So that feebler applications more frequently made, if need be, effect more satisfactory results by instituting in the part a slow process of disintegration to which the normal tissue may adjust itself, and replace by normal growth rather than by scar tissue as would be the case after extensive sloughing.

Metallic Electrolysis:—The metal point or needle which is made use of for an electrode may itself be readily acted upon at the anode by the oxygen and chlorine that is set free at that pole by the electrolytic process, and an oxy-chloride of the metal is formed which of itself has beneficial therapeutic action which may be made use of when the pathological condition is such as to require it. The oxy-chlorides of copper, zinc or silver are all of them styptic and antiseptic in character, and this method of employing them, that is by having the anode made of one or other of these metals, is both a

convenient and efficient way for getting the medicinal effect of these salts upon any part. When employing electrolysis for any purpose the direct current used should be completely under the control of the operator, and should be so managed as to give no disagreeable shock to the patient. This result can be readily attained if one makes use of reliable apparatus and is thoroughly informed as to how to use it.

Before the current is turned on the active electrode should be introduced into or brought in contact with the part to be electrolyzed and the other or dispersing electrode, which ought to be of large size and well moistened, should be in place, either upon the hand of the patient, the back of the neck, or over the breast bone, and then the current should be by the gentlest gradation turned on by means of a rheostat or controller, until the milliamperemeter indicates the desired quantity, and when the application is ended the current should be as gradually withdrawn. Operating in this manner the patient experiences no shock or special discomfort, especially if the precaution is taken, both by patient and operator, during the application to make no break in the circuit at either electrode.

Cataphoresis and Anaphoresis.

Cataphoresis is a term used to designate that action of a direct or galvanic current upon the tissues of the living organism by which substances placed upon the anode are, by the moving power of the current, driven toward the cathode and so carried for a greater or less distance into the tissues. By this means medicinal substances which would not, by mere contact, find their way into the tissues are made to do so and their peculiar effects upon the tissue, either locally or over a wide range, as the entire surface of the body, may be brought about. Since the adoption of the term cataphoresis much has been learned concerning this action of the direct current, which shows that the first conceptions that were entertained concerning it are entirely too narrow. It was thought that this moving power of the current upon substances, in solutions

which were made a part of the circuit, acted only in what is assumed to be the direction of the current, that is from anode to cathode. It was supposed that a substance in order to be conveyed through the tissues by means of the current must be placed upon the anode. But later investigations have shown that this is true only of certain substances, and that others may be made to penetrate the tissues with equal facility if placed upon the cathode, the electric action driving them in a direction opposite to that in which the current is supposed to be traveling, from cathode to anode. The word *anaphoresis* has been suggested as an appropriate term by which to designate this share in the transmission of substances by means of the direct or galvanic current, and the appropriateness of the term recommends it for general adoption. Anaphoresis will therefore be henceforth used in the columns of this *Bulletin* to designate the transmission of medical substances from cathode to anode by means of electric currents.

Relation of Cataphoresis and Anaphoresis to Electrolysis.—Since it has been found that the nature of a substance determines the direction it will travel in a solution, when that solution is made a part of the path of a direct current, strong evidence has been educed to prove that what we term cataphoresis and anaphoresis is nothiug more or less than the migration of the ions in the process of electrolysis; the positively charged ions seeking the negative pole and the negatively charged ions being attracted to the positive pole.

Many experiments arranged to simplify an analyzed the action of these migrations of various substances through the influence of direct currents seem to justify by their results the conclusion that electrolysis has much to do with it.

But in order to explain, by electrolysis, all that occurs in the moving of substances in the one or other direction by means of the electric current, the present conception of the electrolytic process must be enlarged so as to include not only the migration of ions which have become disassociated from chemical combinations through the action of the passing current, but also the migrations of molecules of complex compo-

sition that are suspended in the solutions, and which do not break up into ions prior to obeying the moving power of the current, but travel in their original form, some in one direction some in another, according to their nature. Thus, certain of the coloring matters, such as methylene blue, are made to move from anode to cathode by the action of the current, when suspended in solution in the current's path, while eosin travels from cathode to anode. Many substances, also, which are, by currents of certain strength, broken up into ions and then obey the law of ionic migration, are found to act differently if the current is not of sufficient strength to cause electrolytic decomposition. The molecule of the substance, undecomposed, is found to move in one or other direction, according to its nature and composition, under the influence of these weaker currents. This we think we have, by experiment in this laboratory, proved to be true of potassium iodide and cocaine hydrochlorate, both of which are readily decomposed by the action of moderately strong currents, but the molecule of each may, to a certain extent, be transmitted intact by weaker currents.

Only by experiment can it be determined whether a substance is cataphoric or anaphoric. And, likewise, the strength and density of current necessary to cause a substance to penetrate the tissue as an unbroken molecule, or in the form of ions resulting from it by electric disassociation, must be settled by actual test.

Laboratory Experiments on Electric Diffusion.

Many conflicting and misleading statemeuts have appeared in articles written upon the subject of cataphoresis.

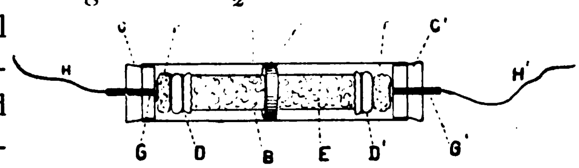
The assumption that a solution of any medicinal substance when placed upon the anode would be carried into the tissues in the direction of the cathode, has been blindly followed by many practitioners of medicine, and dentists also, without question.

Only an occasional observer sought to verify the assumption by tests having the value of a demonstration. Crude as many of these tests have been, they have sufficed to show that certain substances only are cataphoric, while others are anaphoric.

The difficulty in the way of making a satisfactory demonstration of this fact on living human tissues is very great, as can be readily seen. The main obstacle being that we do not have the opportnnity to subject the tissues, at the electrodes and along the path between them, to the chemical tests needed to determine the presence of the medicinal substance used, or of its ions. Some experiments have been made upon animals, as upon the uterus of rabbits by Gautier, with a view of determining the effects of metallic electrolysis, which, at the same time, seemed to exhibit the cataphoric action of the current upon the salts of the metals formed at the anode, for he claims that the salts were carried in by the current so as to stain the tissues for a considerable depth from the anode. We have not as yet had the opportunity to review these experiments in this laboratory, as it is our purpose to do in the near future.

So far we have confined our experiments on the diffusion action of the current to potassium iodide, cocaine hydrochlorate, and to certain of the coloring matters, as methylene blue.

In order to get the conditions for experiment, without the body, as nearly as possible to correspond with those which exist when living animal tissues are made a part of the path of the current, we adopted the following methods: A glass tube, 20 centimeters in length and 2½ centimeters in diameter, enclosing a small glass tube (B) 12 centimeters in length and 2½ centimeters in diameter.



The tubes are separated from each other by a ring of paraffine (L) which prevents communication from end to end, except through the inner tube. The inner tube is packed with pledgets of absorbent cotton (E) soaked in tap-water and the ends covered over with bladder membrane (DD′). Against the membrane pledgets of cotton (FF′) are placed and these likewise are well moistened, the one with tap-water and the other with the solution of the substance upon which the currant is to act. Against these end pledgets of cotton, carbon electrodes (GG′) are placed and the wires leading from the electrode are passed through corks which close the ends of

the larger tube. By this arrangement, whatever current travels in the circuit must pass through the end plugs of cotton, the animal membranes and the cotton pledgets of the inner tube. On whichever end plug the medicinal substance is placed it has no access to the plug at the other end except along that path. By having two pieces of apparatus of this nature, exactly similar in all details, except that one is made the path of a direct current while the other is used as a check or comparison, the action of the current can be determined with accuracy.

Numerous experiments have been made with this apparatus by placing a solution of the substance experimented with on one or the other end plug and causing currents of varying strength to traverse it for different periods of time, and then examining by chemical tests the composition of the solution in the various pledgets of cotton which filled the tube through which the current had passed, as well as of those through which there had been no current.

Potassium iodide is a substance which, by reason of its reputed action in promoting absorption of exudates and abnormal growths, is often given internally for this purpose. As it is the local effect which is usually what is needed, the attempt has been frequently made to introduce this remedy into some parts of the body by means of the diffusing power of the electric current. Some have advised placing the solution upon the anode while others have insisted that the cathode is the electrode to select for driving this remedy through the skin and into the subcutaneous tissues. We attempted to settle this question by a series of experiments with a ten per cent. solution of potassium iodide and the apparatus above described. It would be tedious and unprofitable to go over in detail this series of experiments, which were carried on daily for some weeks. It will suffice to state that the results seem to show,

1st. If the potassium iodide solution is placed in contact with the anode and the current used is of therapeutic strength and density (that is, not exceeding two or three milliamperes for each square centimeter of electrode surface,) it will electrolyze the potassium iodide in the immediate vicinity of the anode,

the iodine remaining at the anode, while the potassium hydroxide is driven toward the cathode.

2d. If the potassium iodide solution is in contact with the cathode and a current of like strength and density is used, the potassium iodide is carried toward the anode and is not electrolyzed until it reaches the anode. Decomposition then takes place, iodine is set free at the anode and the potassium appears to return to the cathode since, subsequent to decomposition at the anode, the alkalinity at the cathode increases.

Currents of the above mentioned strength and density were preferred for these experiments, since they correspond to such as are most frequently employed in theraputic applications. The electro-motive force of the current was about fifty volts. An increase or decrease in voltage or strength of current within reasonable limits, did not appear to modify the result, as above mentioned, except as to the time needed to effect it. A greater voltage or strength of current would shorten the time, while a less voltage and current would require more time to get the same degree of polar changes in the solution.

With cocaine hydaochlorate the results of experiments have not as yet been so exact and convincing. This is chiefly due to the fact that the chemical tests employed to detect small quantities of cocaine are not satisfactory. The physiological test with this agent are more reliable, and of these we have made many. The strength of the hydrochlorate of cocaine solution used was four per cent., the time of application ten minutes, and the current strength and density two or three milliamperes for each square centimeter of electrode surface. These physiological tests seem to justify the following conclusions:

1st. That cocaine hydrochlorate solution is cataphoric.

2d. That with the strength and density of current ordinarily employed in therapeutic applications there seems to be no decomposition of the cocaine hydrochlorate at the anode.

3d. That a much more decided anaesthetic effect is caused by applying the cocaine solution by means of the electric current and the anode than would result from a corresponding

application of the current by means of the anode, but without the cocaine solution.

Methylene blue, when suspended in water, is found to be cataphoric and can be conveyed into the pores of the skin by currents of very feeble density. The customary experiment in this laboratory is for the experimenter to place one hand in a glass jar partially filled with methylene blue solution and containing the positive electrode, while the other hand is placed in an equal amount of the solution in another jar, with the negative electrode. The current is allowed to pass, for twenty minutes, at an electro-motive force, not to exceed fifty volts, which would allow but a very feeble density of current over so large a surface as the hand. When the hands are withdrawn it is found that the blue color can be readily removed, by washing, from the hand that was associated with the negative electrode, but in the other hand the stain has penetrated so far that it requires several days before ordinary washings cause it to disappear, so deeply have some of the particles been carried into the hair follicles, the mouths of the sweat glands and crevices of the skin.

Apparatus for Electrolysis and Electric Diffusion.

The direct or galvanic current is necessary when an operator wishes to get the decomposing or the diffusion effects of electricity.

Induction coils, alternating dynamos or static machines do not furnish currents suitable for this purpose.

The physician or dentist can get a direct current from any one of the following sources.

1st. Primary batteries.

2d. Storage batteries.

3d. Direct current dynamo circuits.

The comparative value of these sources of current has been fully discussed in Vol. I of this *Bulletin.*

The amount of current required by the dentist for electrolysis or electric diffusion (cataphoresis and anaphoresis) is very small. Seldom more than five milliamperes are needed,

and usually much less than this. There are several reasons why so little current is required. In the first place, the active electrodes that are employed are, as a rule, quite small, making the current density at the point of application even greater, with one or two milliamperes of current flowing in the circuit, than is customary in therapeutic applications. And in the second place, the resistance offered by the tissues is much less when one of the electrodes is either buried in the tissue or upon a mucous surface, as is the case in the majority of applications about the mouth. The parts about the mouth upon which the dentist is required to operate are ordinarily quite sensitive and electric applications need to be much more carefully managed than when applied to less sensitive parts of the body. More important than the source of current are the appliances for controlling and measuring it.

A rheostat which will permit of a gentle and gradual admission of the current into the circuit, after the electrodes are in place, up to the strength and voltage required, maintaining it there without fluctuation, and, when the work is done, permitting a like gentle and gradual withdrawal of the current is the most essential factor in the series of appliances for electric applications. If, in circuit with such a rheostat or controller, a reliable milliamperemeter is placed, registering on a wide clear scale, not to exceed five or ten milliamperes of current, the next most important requirement for successful work with direct electric currents will be met. Fortunately, both these most essential pieces of apparatus have, at present, been brought to a high degree of perfection by the instrument makers. For controlling currents of a strength and voltage such as dentists require for electrolysis and electric diffusion, a reliable graphite rheostat of unvarying resistance, arranged on the shunt principle, is a most satisfactory instrument, for by

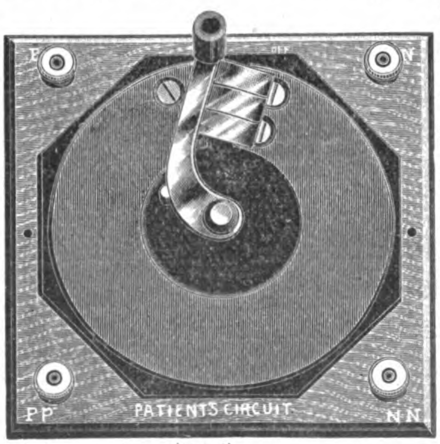


Fig. 2.

means of it current and voltage may be increased or decreased in the circuit with equal step from zero to any required amount. The accompanying illustration (Fig. 2) represents such a rheostat, and the following diagram (Fig. 3) explains its manner of controlling the current. Suppose the wires from the battery or other source of current are attached to P and N, and that the current enters at P and goes out at N, by way of screwhead A, S′, S and A′. This is a distinct circuit for the current, between A and A′, through which it meets with a uniformly graded resistance of graphite of several thousand ohms, between which points there is a difference of potential corresponding

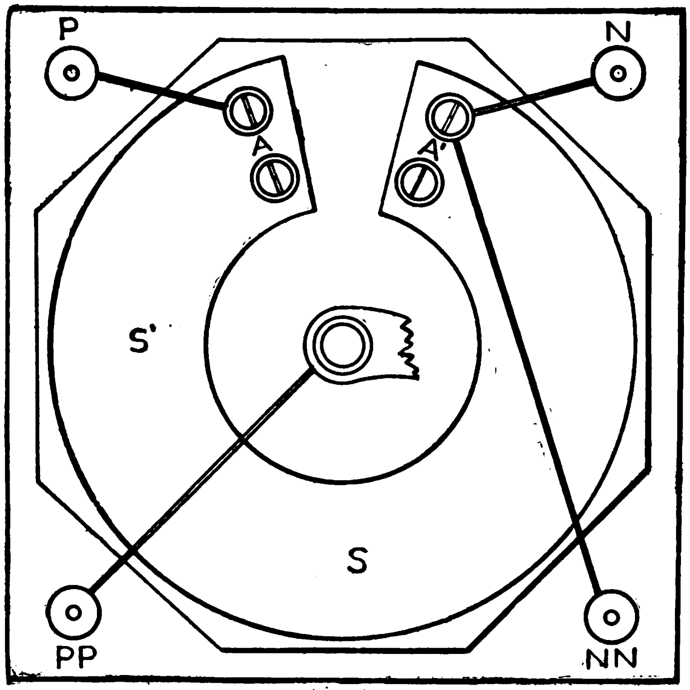


Fig. 3.

to the electro-motive force of the circuit with a uniform drop in that potential all along the line. If the rheostat is on a battery circuit of 20 volts, such as would be furnished by fifteen Le Clanché cells in series, at the middle point in the rheostat, S, the voltage would be 10, while at S′ and at its opposite point it would be 5 and 15 respectively. Now, if a rotating arm, with a sliding contact moving over the graphite surface, is connected with binding post PP, and screw-heads A. are connected with binding post NN, which, with PP, form the binding posts for the patient's circuit, then the amount of

current and voltage that is admitted to the patient's circuit will depend, according to the law of divided circuits, upon the position of the radial arm upon the graphite surface. By moving this radial arm from A′ the operator admits to the patient's circuit the required current in the gentlest and most uniform manner and with no shock to the patient caused by a sudden variation of potential, provided the patient or operator does not break the current at one or other electrode while the current is passing.

As to the milliamperemeter, it should, as has been said above, have a clear, distinct scale which need not cover a very wide range ; five or ten milliamperes is quite enough. The type of milliamperemeter which is provided with its own magnetic field will be found most convenient, since such an instrument is not disturbed by the inductive influence of currents flowing near it, nor is the needle diverted by iron or steel in instruments, in the operating chair, or other objects in the room, which it is often difficult if not impossible to keep a sufficient distance from it so as to avoid this effect.

The electrodes will vary in design, according to the nature of the work that is to be done with them. Precision in the application of the electric action is what is wanted with the active electrode and this result is always best obtained when, throughout the application, the hand of the operator holds it and his eye guides it. While the current is passing if it is not doing the work that it is intended to do it is, in all probability, doing harm, and it needs the intelligent guidance of the operator's hand directing it at every moment of the application,

The dispersing or other electrode can be placed at any part of the body most convenient for the patient; the palmar surface of the hand, the upper surface of the breast or back of the neck. It should be of good size, 4 by 6 inches, at least, of metal well covered with absorbent cotton or amadou so as to offer but little resistance to the current and distribute its density over the entire surface.

The operator who succeeds in making electricity his obedient servant will find it most helpful, but it is only by attention to such details as are here suggested that the efficiency of this service can be discovered and appreciated.

The Sedative and Stimulating Action of the Direct or Galvanic Current.

When an anæsthetic medicine, such as a cocaine salt, is used cataphorically it is not right to attribute all of the benumbing effect that follows to the sedative action of the cocaine alone. It is well known that the play of the direct current has, of itself, in the vicinity of the anode a sedative effect upon sensitive nerves and reduces the excitability of motor nerves. On the contrary, the effect of the current on nerves, in the neighborhood of the cathode is exactly contrary, irritating and exciting them. We have long been accustomed to explain these contrary polar effects in nerves to the electrolytic changes and the modification in their condition caused by electric diffusion.

The greater acidity and diminished fluidity which results in the neighborhood of the anode from the flow of a direct current are apparently conditions unfavorable to the physiological activities of nerve tissue, while the increased fluidity and alkalinity which is created about the cathode increases such physiological activity. These changes in physiological states resulting from the action peculiar to one or the other pole of a direct current can be turned to advantage in therapeutics. An irritable nerve, as in dental or facial neuralgia, can be reduced in sensitiveness by subjecting it to the anodal influence of the current and on the other hand nerve activity can be aroused and a better state of nutrition brought about, when it is desirable, by a judicious employment of the excitant and stimulating action of cathodal applications.

Unintentional Electrolysis in Dentistry.

It is an old and familiar trick to make a simple galvanic battery of the mouth by taking two pieces of different kinds of metal, as a copper and a siver coin, and placing one upon and the other beneath the tongue, but so that their margins are in contact at one point, have a current generated that is quite perceptible to sensation.

The sensation is much more noticeable if the coins are in contact at one point, but such contact is not necessary for the creation of a current between them, as we have often demonstrated by delicate meters placed in circuit the current is pres-

ent when they are not in contact, though not so strong. What is thus seen to take place when two dissimilar metals are temporarily placed in the mouth, continually goes on when two dissimilar metals are used in the mouth as fillings. Tin and gold, as they have the greatest difference in electric potential, excite the strongest currents of any metals used for fillings, and the evil effects resulting from such electrolytic action and continuous flowing, of even minute currents, more quickly follow when this combination of metal fillings is used; but many other combinations, such as gold and amalgam, or amalgam and tin, or, as I believe, amalgam and amalgam will bring about harmful effects, though, perhaps, not so quickly or to such a marked degree. I could cite numerous instances in my practice where this cause alone, owing to the destructive changes due to the electrolytic action of the current on the nerve terminals and other tissues, as well as the nerve exhaustion resulting from the continuous excitation of the current, was followed by neuralgias of the trigeminus and deafness which were in no manner relieved until such lack of harmony in the metal fillings was corrected. Changing the fillings to one metal was followed, in these cases, by prompt relief.

Many dentists have given me strong testimony from their experience confirming these conclusions. It is not needful that the different metals are in teeth which come in contact in the action of the jaws, for the saliva will serve as a conducting medium for transmitting the current, but, if the dissimilar fillings are widely separated in the mouth, the currents between them will be feebler and the iujurious effects resulting will be correspondingly less.

W. J. HERDMAN, M. D.,

Professor of Diseases of the Nervous System, University of Michigan.

VOLUME IV. APRIL, 1897. NUMBER 2.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN.

Published Quarterly by The Inland Press, Ann Arbor, Mich.
Subscription Price, One Dollar a Year.

High Potential, High Frequency Currents.

Currents of high tension and of great frequency of alternations have long been known to the electro-therapeutist who is familiar with the action of the static machine. The discharge which takes place between the prime conductors of such a machine, when they are supplied with Leyden jars or condensers, is at times of this nature. During the small fraction of a second required for such discharge, which may be spoken of as an instantaneous current, the electric polarity changes many thousand times, in oscillations of gradually diminishing amplitude. When the arrangements during a treatment with the static machine in action is such as to make the patient on the insulated stool the terminus of the charge from one of the condensers, and a ball electrode connected to the other condenser is brought sufficiently near the person of the patient to permit a spark to pass i. e., the direct or indirect treatment by sparks, then, provided the relation of capacity to resistance is just right, the patient is subjected to a current of high frequency and high potential for the instan

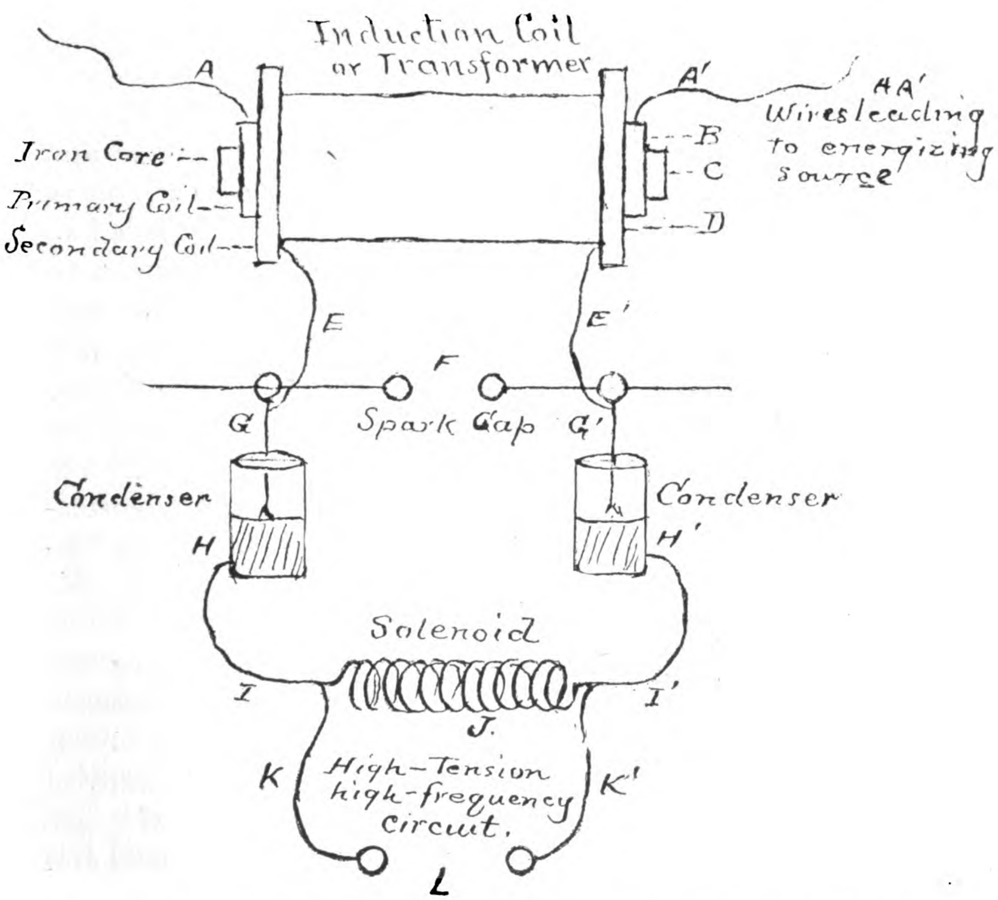
corresponding to each discharge. Again, the static machine may give rise to high frequency, high potential currents in what has been termed the *static induced circuit*, a current that is obtained in a circuit connecting the outer surfaces or armatures of the Leyden jars or condensers. The patient may be made a part of this circuit and so be subjected to the influence of these high potential, high frequency currents.

But as one of the important features of this peculiar electric modality in its relation to physiological and therapeutic action is the oscillatory character of the discharge, the static machine as it is customarily employed cannot be depended upon with certainty to furnish a discharge of this nature. Whether or not the spark discharge of the static machine is *impulsive* or oscillatory in character depends upon the relation which the capacity of the machine and condensers bears to the inductance and resistance of the circuit, and as certain of these terms vary from time to time, due to atmospheric conditions and manner of application the physical nature of the discharge likewise varies, and therefore the static machine, in the arrangement of its parts as now employed in therapeutics, does not furnish the high potential currents with such invariable regularity in number and frequency of the oscillations as is required for accuracy in scientific observations and comparison of results.

If the output of electric energy from the static machine was stabile and uniform the capacity of the condensers could be so adjusted to the resistance and inductance in the circuit as to secure constancy in the oscillatory nature of the discharge from them, but the obstacles to this end have not yet been overcome.

Other sources than the static machine have therefore been sought for and developed for generating high potential, high frequency currents. Tesla, Elihu Thomson and d'Arsonval have each been active in this search, and each in his independent line of investigation has made use of large induction coils as step-up transformers of the the original electric energy, which in some instances is derived from alternating dynamos of low frequency and in others from some direct current

source, as a dynamo, a primary or secondary battery. The low frequency of the alternating dynamo must be changed to a high frequency, and the constant or direct current must be broken up into sudden impulses with interruptions in order to furnish the proper variations for inducing currents in the windings of the induction coil. These necessities give rise to some peculiarities in mechanism which have been variously con-



structed by the different inventors. The underlying principles by which the ultimate result is secured are the same in all. The accompanying diagram will illustrate the various steps in the process.

B C D is an induction coil or transformer whose primary coil is energized from some source, preferably an alternating current dynamo. If the energizing current is a direct current

source then the primary circuit would need to be supplied with an interrupting device to break the current into periods, such as the spring vibrator attached to the ordinary induction coils or, what is better, a rotating disk driven by a motor and so arranged as to make and break the circuit with great rapidity and suddenness, as in the method devised by d'Arsonval. With the primary coil excited in either manner named, induced currents are created in the secondary coil D, the terminals of which are joined to the internal armatures of two condensers or Leyden jars G G′, between which is arranged a spark gap F. The external armatures of the condensers H H′ are joined through a solenoid J of copper wire of large size and about 20 turns. When this system is in action, at each break or alternation in the primary circuit, the E M F induced in the secondary coil charges the condensers. In proportion to the charge the difference of potential between the armatures increases. When it reaches the limit of the area of the ball terminals and the space separating them at the spark-gap, which may be many thousand volts, a discharge takes place across the air gap and oscillates between the condensers, while the solenoid J is traversed by a current of a frequency corresponding to the frequency of the oscillations. These oscillations are prevented from discharging into the circuit of the secondary coil because of its great self-induction. When operating the system by energizing it from an alternating dynamo circuit the charging and discharging of the condensers is so frequently repeated that an arc is likely to form across the spark gap and so put an end to the oscillatory nature of the discharge. In order to prevent the formation of this arc Tesla and Thomson employed first, a strong magnetic field and later, an air blast at the spark gap.

When we compare the action of this system when energized by the alternating dynamo current, or the interrupted direct current, we find that with the first the inductive effects of the two waves of positive and negative potential are the same, so that when the alternation has a frequency of 124 periods per second as is customary with the ordinary alternating dynamo used for industrial purposes, there will be double

the number or 248 single inducing waves each second. With the direct current interrupted a current effective in charging the condenser is induced in the secondary only at the instant of "make," so that to have the same number of useful waves as with the alternating dynamo current, it would be necessary for the interrupter to produce 248 contacts per second.

The currents that traverse the solenoid induced by the discharge of the condensers to the outer armature of which the solenoid is connected are those that are ordinarily utilized for therapeutic purposes. By connecting conductors to each end of the solenoid a circuit can be provided through which these currents can be conveyed. This may be termed the patient's circuit, for it is to the current generated at this point that the patient is, in one or the other manner, subjected.

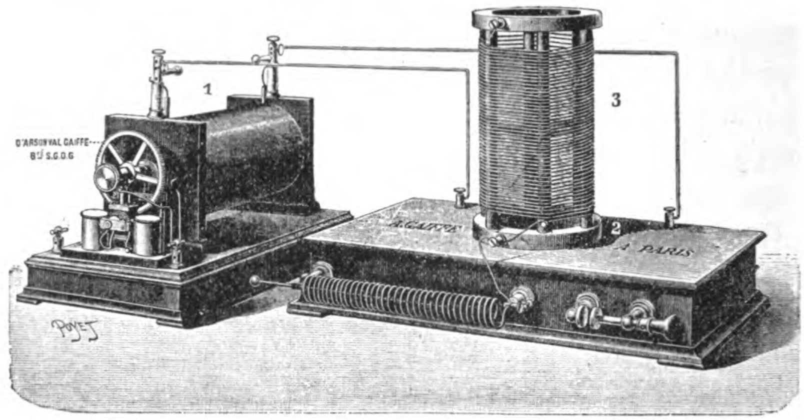
By an additional device, that is another step-up transformer, these currents may be brought to generate others of still higher tension. These have been termed "currents of second order," and are obtained by having the solenoid of sufficient diameter to permit of placing within it a glass tube enclosing a coil of fine, well insulated wire, of many turns but a single layer. Currents of such extremely high potential are excited in this inner coil when the solenoid is excited that the glass tube surrounding the coil of fine wire needs to be filled with oil to serve as an insulator. The terminals of this fine wire coil brought out at the extremities of the glass tube through proper stoppers can then be connected up in a manner desired so as to exhibit the nature of these "currents of second order."

Hertz, Tesla and Thomson have each devised a number of beautiful and striking experiments by which to demonstrate the energy possessed by these high frequency and high potential currents. It was early discovered that they failed to excite the animal organism either in the form of sensation or muscular movement, and yet after traversing the body they render lamps and vacuum tubes incandescent, and in many ways exhibit an expenditure of electric energy which if applied to the animal body in one of many other forms would prove instantly destructive.

As pointed out by Bordier, these currents are distinguished from ordinary alternating currents by three essential properties, which are due to both the great frequency and the high tension.

1st. They cause remarkable inductive effects.

The E. M. F. of induction near an inducing source is equal to the product of the intensity of the current by the frequency. Let us suppose a frequency of 500,000 periods



D'ARSONVAL APPARATUS.

per second and a mean current of 1 ampere. The E. M. F. in one turn would be the same as if a current of 100 amperes with a frequency of 50 should circulate in 10 turns of wire. Thus it is seen that with high frequency the E. M. F. induced in a single turn would be considerable. In a large solenoid the current induced in one turn is sufficient to illuminate by mutual induction a lamp of 8 volts and 1 ampere.

2nd. Currents of high frequency, even though the capacity be small, circulate as well in open as in closed circuits, so that contact with only one pole suffices to give a current.

In fact, feeble as may be the capacity, the charge and discharge, repeated hundreds of thousands of times per second at a high potential, represent a notable mean current.

It is this that explains the uni-polar currents and the sparks that occur when any point on the solenoid is touched. In this case the body constitutes an insulated surface which,

at each oscillation, is charged with a very nearly constant quantity when it is at a certain distance from the solenoid.

The corresponding charge of contrary sign should be found on the parts of the solenoid which are at that moment at a different potential. This explains why the sparks which are drawn from the solenoid are greatest at the extremities and least midway.

3d. The resonant effects, which have been so beautifully shown by the experiments of Hertz, and which are extremely interesting to the physicist, but which have not, so far, been found to have any relationship to therapeutics.

In bringing the action of these high frequency currents to bear upon the human and other animal organisms three methods of application have up to this time been employed—suggested by the properties of the current which we have enumerated.

1st. Auto-conduction. In this mode of application the capacity of the current to induce currents in objects brought within their range, is utilized. In place of the small solenoid above described a much larger one is employed, composed of well insulated cable wire, and wound about a frame work capable of admitting into its interior the man or animals to be treated. Although the person enclosed in the solenoid is not in contact with it at any point, nevertheless, while it is in action, induced currents of extreme energy and frequency of oscillations are induced in his body. These induced currents have their seat in the organism itself and act upon the central nervous system and deep seated organs and tissues as is shown by the effects produced and recorded in the following article on the physiological action of these currents.

2nd. The direct application. This is made by conducting the currents generated in the small solenoid, or the currents of second order, to any part of the body by means of conducting wires and metallic electrodes and thus making the body as a whole, or any part of it, as the case may be, a part of the circuit.

3rd. Insulation. In this method the patient, person or animal, to be subjected to it is placed upon an insulated plat-

form and connected by a wire to one extremity of the solenoid while a point, metallic point or plate, at some little distance from the insulated platform is connected with the other extremity of the solenoid. The person acted upon is thus, as it were, made to take the place of one of the armatures of a condenser and is subjected to a charge which is slowly discharged by connection across the interval between the body and the conductor leading to the other extremity of the solenoid.

Physiological Action of High Tension, High Frequency Currents.

This form of electric modality, except as it is furnished by static or influence machines has not so far been studied in its relation to physiological action by many persons. Several notable electricians as Nikola Tesla, Elihu Thomson and Hertz have done much to acquaint us with the apparent harmlessness of this form of electricity when the living animal body, or some part of it, is made the path of its transit. But to d'Arsonval and his assistants, the credit is mainly due for having determined with scientific exactness and demonstrated by unquestionable proofs that this electric modality does in many ways modify physiological processes most profoundly. While we have for a number of months been using this form of electricity in this laboratory, as generated by both the Tesla and the Thomson forms of apparatus, we have, so far, done little with it other than to confirm many of the results that d'Arsonval has reached and which he has published from time to time in the transactions of the Société de Biologie and of the Société Internationale de Physique.

What is set forth here, therefore, as the result of investigation as to the relation of this form of electricity to physiological action in the animal body, and which may be regarded as fully established by abundant experiment, is given mainly on the authority of d'Arsonval, and to the detailed reports of his researches we would refer any who may wish to examine into the data upon which the following conclusions are based.

1st. The most singular and striking effect of high-tension, high-frequency currents is their entire absence of action on sensation. This is daily demonstrated in this laboratory. When the Tesla apparatus is excited by an alternating dynamo current and is pouring forth a torrent of sparks between the terminals, across an air gap of eight or ten inches, one can grasp these terminals, one in each hand, and take the entire current through the body without experiencing the slightest sensation except, perhaps, one of gentle warmth at the wrists when the current reaches, or exceeds three amperes. To demonstrate the actual energy that is being expended during this procedure it needs only to have two persons grasp these terminals each with one hand and then complete the circuit by taking several incandescent lamps in series between them, when these lamps, requiring each an ampere of current and 100 or more volts to light them, will glow brilliantly while the current is passing.

When the current is caused to impinge upon a limited surface of the skin or mucous membrane in the manner which in treatments by the static machine is termed "the breeze" the part is soon benumbed and for a few moments experiences loss of sensibility which may go on to complete anaesthesia. This insensibility does not penetrate deeply and lasts only a few moments, but that it may be made to serve important therapeutic needs is at once evident to a physician.

2d. These currents do not excite muscular contractions. Just as the passage of these currents through the organism fails to arouse sensation so likewise motor nerve and muscle are irresponsive to them. While the same quantity of electric energy transmitted under the form of alternating currents of long periods (100—10,000) and much less voltage, would have caused violent muscular contractions, which of themselves would suffice to kill the recipient, here no contraction whatever occurs.

But just as a sensory nerve when subjected to the direct action of these vibrations for a time is rendered anaesthetic, so a motor nerve may be influenced in such manner by these

currents as to be for a brief period (10 to 15 minutes) incapable of responding to any form of excitant.

3d. The high-tension, high-frequency currents impart an extraordinary activity to nutritive changes and to cellular life.

This has been demonstrated.

(a) By examining and estimating in man and animals the products of respiratory combustion before and after the action of the current. The oxygen absorbed is seen to be increased considerably and carbon dioxide is eliminated in greater quantity.

(b) By the amount of urea being greatly increased in quantity, as has been determined by hundreds of urinary analyses.

(c) By an increased heat production, which has been carefully determined by an ingenious anemo-calorimeter devised by d'Arsonval. By this instrument it has been established that by comparing the heat put forth by the human body before and after this method of electrization, it is found to raise it from 79.6 cal. to 127.4 cal. per hour at an average temperature of 17° C.

(d) By a loss of weight in the men and animals experimented on during the period of application. This would of necessity be the primary result of the increased combustion. But it was found that in the intervals between the applications of the current there was a rapid gain in weight.

4th. While there is no perceptible action of these currents on the nerves of general sensibility and of voluntary muscle, the vaso-motor nervous system which controls the vascular system is influenced by these currents to a marked degree. The blood vessels in the ear of the rabbit are seen to dilate rapidly under its action and this is followed a little later by energetic contraction. The same results take place in man as determined by the sphygmograph and sphygmomanometer. The blood pressure is at first lowered and after a little time rises and remains elevated.

5th. Action on unicellular organisms. In order to determine the direct action of these high-frequency, high-tension currents on cellular physiology many forms of bacilli were subjected to their influence. The cultures of the pyocyanic

bacillus were very much attenuated at the end of some minutes. The chromogenous function is first suppressed and if the experiment is continued for half an hour the baccilli are killed.

The action of these currents is found to modify also the products of the secretion of bacteria. The microbic toxines are found to readily lose their virulence when subjected to this electric modality for a short time.

D'Arsonval and Charrin have carried on a series of experiments for some months to determine the modifying action of various forms of electricity on the growth and behavior of bacteria the results of which were reported to the French Academy of Sciences, February 10th, 1896. Their experiments have shown that cultures of bacteria are affected more or less by the action of the constant or galvanic current, the interrupted induced current of low tension and frequency, and also by the high tension, high frequency currents. The action of the latter seems to be most effective both in retarding the growth of pathogenic bacteria and in weakening the virulence of their toxine products. As has been elsewhere noted, the action of the constant current upon culture media is attended by electrolysis and it is a difficult matter to determine, when this current is used, just how much of the result is to be attributed to the electric action directly and how much to the action of the liberated ions. It is fair to presume that the changes wrought by the high tension, high frequency currents are the result of the electric action solely since being alternating currents but little electrolytic decomposition attends them.

The experiments upon bacterial toxines by means of high frequency, high tension currents and the subsequent tests made with the solutions containing the toxines thus acted upon, not only seem to show that the toxic power is reduced, but also that the animal receiving such injections is rendered immune, or its resisting power to such toxines is greatly increased. From this the hope is entertained that by means of the application of such currents it may, eventually, be possible to so attenuate bacterial products in the organism of a patient as to render him immune to the disease.

6th. The clinical results are also in evidence to prove the modifying influence which electricity in this form exerts upon physiological action, and while these are not as yet very abundant they are already sufficient in amount and importance to establish the value of this unique manner of treatment, and are deserving of separate consideration in the following article.

Therapeutics of High Frequency Currents.

Those who have been long familiar with the results obtained from treatments by means of the static machine cannot but be struck with the similarity of these with what has recently been set forth by d'Arsonval, Apostoli and a few others as the results of their experience in the therapeutic use of high frequency currents obtained through the variously devised forms of apparatus that they have employed. Especially do the results on general nutrition obtained by the spark and insulation methods of treatment by the static machine closely correspond with those reported as resulting from the inductive action of the large solenoid. The assertion which is often made that "suggestion" is accountable for much that is reported as resulting from this as from other forms of electric treatment falls to the ground in the face of the exact methods of analysis that have been adopted in determining the effects of these currents on patients in the public clinic and upon the growth of infants in the Maternity hospital. But the field is open and those who doubt may readily put all assertions to the proof.

We perhaps cannot do better in our attempt to set forth the present state of opinion as to the therapeutic range and value of this peculiar electric modality than to give as succinctly as possible the conclusions of Apostoli, whose clinical experience in this field has been up to the present time far more extensive than that of any other practitioner.

They are as follows:—

1st. The alternating currents of high tension exercise a powerful action on every living organized body which is submitted to their influence.

2nd. The best method of treatment by means of these currents is to enclose the patient, without any contact whatever, in a large solenoid traversed by the current. The patient is thus completely insulated from the electric source and the currents which circulate by "auto-conduction" in his organism have their origin, by induction, in the tissues themselves. The body here plays the part of a closed circuit.

3rd. The powerful influence on the vaso-motor system claimed for these currents by d'Arsonval has been verified, although the sensation immediately produced by their passage is nil, and there is no impression made by them on motor nerves or muscles. But an energetic action on all nutritive exchanges may be noticed. This action shows itself by an over-activity of organic combustions and of nutrition, as has been shown by the analyses of the respiratory and urinary excretions made by d'Arsonval, Berlioz and others.

4th. The general therapeutic applications which follow from this physiological action are confirmed in the clinic.

At the time of this report (made at the London congress in '95) Apostoli had in this manner treated more than one hundred patients, covering a period of a year and a half, some in his office and some in his public clinic. The greater number of them were much benefitted by this method, which was used to the exclusion of all other treatment or medication.

5th. These currents exercise, in the majority of cases, a powerful and generally reparative action on diseases caused by or attended with feeble nutrition, by accelerating the organic changes and by increasing the activity of enfeebled or perverted combustion and elimination. Diuresis becomes generally more satisfactory and excretion is hastened.

6th. Generally in patients submitted to this influence daily for about 12 minutes the following effects are noticed about in the order named:—

Return of sleep.

Increase in force and vital energy.

Return of good feeling, capacity to work, ease in walking, increase of appetite.

Progressive and complete restoration of the general health.

Often from the first sittings and even before the special and local effects are noticed as changes in the excretions, etc., an amelioration of the general ill-state can be plainly noted.

7th. The local troubles, pains or trophic disturbances, subside generally much more slowly under the modifying influence of these currents than general nutritive disorders. In many cases such local disorders require the addition of local treatment.

8th. Of all the diseases, which up to the present seem to yield to this treatment, rheumatism is most energetically and effectively influenced.

9th. In some cases of diabetes the sugar has rapidly disappeared from the urine, while in others it has not been perceptibly diminished in spite of the manifest improvement in the general state. This difference in result may be due to a lack of uniformity in technique or to different pathological conditions.

To sum up in the words of d'Arsonval, electricity in the form of high tension, high frequency currents is the most powerful modifier of the intimate nutrition of the tissues that we know.

It is a modifier which attacks life in its most intimate manifestations and which touches the working of the living cell itself. Its action extends even to the products of the cell. As these currents can with impunity traverse the organism of living man there is no temerity in saying that by means of them an entirely new road for therapeutics is opened up.

Notes.

A New Tesla High Frequency Coil.—During a recent visit to the laboratory of Mr. Nikola Tesla, among many interesting things shown me by him, was a new form of high tension, high frequency coil and condenser, which promises to meet the needs of the electro-therapeutists in a most conveni-

ent and satisfactory manner in generating the kind of currents of which this number of the BULLETIN treats.

By a skillful construction of the condenser, both in capacity and material, Mr. Tesla has been able to dispense with the oil immersion in which the coils constructed by him previously had to be imbedded. The coil is also quite compact, and so constructed that it is possible to energize it either by means of a direct or alternating current. As an exciter of X rays I have seen no form of apparatus that could approach this coil in efficiency. By means of it the ordinary form of Lenard tube becomes a source of X rays capable of producing the finest definition in structure of bone and other tissues, a result which confirms Mr. Tesla's opinion that Lenard fell short of obtaining all that Röntgen discovered only because the voltage he employed was not high enough.

W. J. Herdman.

Preparation of Antitoxines by Electricity.—Bonome and Viola taking up the researches of d'Arsonval and Charrin on the action of electric currents on bacterial toxines have sought to produce a streptococcus antitoxine by using high frequency alternating currents, furnished by a Tesla transformer receiving the current of a large Ruhmkorff coil. The virulence of a culture made in bouillon and human serum, or ascitic fluid, was from 1-500 to 1-800 for a rabbit, death occurring the fourth day.

Their conclusions can be summed up as follows: High tension alternating currents destroy the virulence of a culture of streptococcus pyogenes without altering the chemical reactions of the culture, or modifying the morphology of the microorganism. The electric action seems to take place principally on the toxine in solution; the microbe itself can live more than two weeks in an electricized culture.

The antitoxine thus obtained presents the same effects, only more intense, as that of the serum of immunized animals, as they can neutralize in a glass tube 10 times their volume of a virulent culture.

Centralbl. fur Bacteriol, Nos. 22 and 23, 1896.

VOLUME IV. JULY, 1897. NUMBER 3.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN.

Published Quarterly by The Inland Press, Ann Arbor, Mich.
Subscription Price, One Dollar a Year.

Electricity as an Aid to Surgery.

There are very many ways in which the use of electricity may aid the surgeon in his work. Not only the general surgeon but all specialists such as the oculist, the aurist, the laryngologist, the rhinologist and the gynecologist should be equally interested in this matter, for the duties of each of these involves much surgical work. But in the present number we will address ourselves especially to the work of general surgery, and in future numbers the applications to these various specialties will be considered.

The constant or direct current—that form of electricity known to many as galvanism—is the form most useful to the surgeon, since by means of it a variety of tissue changes can be brought about, which may be turned to account in the removal of abnormal conditions.

Certain of the effects of the direct current that may be so utilized are electrolytic, others cataphoric, while in some cases the results must be attributed, in part at least, if not wholly to the effects of the current in modifying nutrition.

Indirectly this current may also give valuable service by heating a cautery—the electric-cautery, and by furnishing a light in convenient form for purposes of diagnosis, but for these uses the alternating current is quite as serviceable and oftentimes more manageable.

Surgical Applications of Electrolysis.—Those doing surgical work who are not acquainted with the electrolytic effects of a direct current upon living tissues will be surprised to learn how wide is the range of its application as a corrective or curative agent.

A direct current when passed through living tissues causes at the point of contact of the positive electrode or anode, provided the current is of suitable strength, an accumulation of oxygen, chlorine and the acids. These by combining with the albuminoids in the adjacent tissues cause coagulation, drying and shrinking the tissue in immediate contact with the electrode. This effect can be brought about in any structure therefore when such an action is likely to prove helpful.

About the negative terminal or cathode, on the contrary, the alkalies and hydrogen accumulate and these have the effect of softening and liquefying the tissue adjacent to the electrode, and there are many abnormal conditions met with, requiring surgical interference for relief, where this action would meet the indications.

Local derangements of blood vessels, such as naevi, cirsoid aneurisms, aneurisms of larger vessels, hemorrhoids, hemorrhagic mucous membranes, or abnormal vascular growths of whatever sort, can have the excessive blood supply, which here is the main pathological feature to contend with, cut off neatly and easily, and without resulting scar tissue, by the styptic effect of anodal electrolysis.

Any abnormal growth may be arrested or removed by robbing it of its blood supply, and we have in this a simple and efficient means for bringing this about. Such growths when treated in this manner gradually shrink and are absorbed, leaving in most instances no evidence of their former presence.

The softening and liquefying effect of cathodal electrolysis is especially serviceable in the removal of non-vascular, dense, horny or warty growths or bony and cartilaginous tissue. Cicatricial tissue resulting from burns, wounds or inflammations is of this dense non-vascular kind and is oftentimes nature's best effort at repair. But it not infrequently happens that cicatricial tissue by its very nature, since it is less pliable and elastic than the normal tissue it has replaced, is itself a serious obstacle to proper function. Especially is this the case when it forms along the course of a duct or canal as the nasal duct, the Eustachian tube, the œsophagus, the urethra or the uterine canal, and by forming dense and unyielding bands or patches at one or more places, causes constriction or strictures of the lumen of these canals. Such strictures, as we know, are serious obstacles oftentimes to proper function and grave derangements may result from them. The customary surgical methods for relieving such strictures are forcible slow or immediate dilatation, or cutting. Either of these methods must result, in the vast majority of instances, in the subsequent formation of still more cicatricial tissue through nature's efforts at repair and the stricture is renewed, perhaps made worse than before. Negative or cathodal electrolysis, when properly employed, meets the conditions necessary for relief in most instances of cicatricial stricture of canals, in a much more scientific and efficient way than by other methods now employed. A suitable electrode, insulated except at the point where action is desired, is passed into the canal so as to locate the electrolytic action in the vicinity of the constricting band or patch; the electrode is made the negative pole of the current which is then carefully turned on and not increased beyond 3 or 5 milliamperes. The anode can be placed at any convenient spot, such as the breast, back of the neck, hand, thigh, or abdomen, but should be large and well moistened. At the cathode, with a current of this strength, the alkalies, potash and soda, together with free hydrogen gas begin slowly to accumulate, and by cataphoresis an increased quantity of moisture is brought to the spot. Through this combination of influences the cicatricial patch or band is softened, rendered

lax and yielding, and experience shows it will be absorbed, in part at least, after a succession of such applications; the change in conditions brought about by such interference aiding the physiological processes to remove it. Certainly in this we have a method for dealing with strictures superior to cutting or forcible dilatation.

The same softening, liquefying action of the cathode may be employed where fibroid, cartilaginous, osseous or non-vascular epithelial growths require removal. The change started in such morbid growths by cathodal electrolysis seems to be just the aid needed to enable the nutritive action present to resume its normal course.

Not the least among the advantages offered the surgeon who adopts electrolysis for the removal of such abnormal growths as are suited to this method is the fact, that, when properly done, it leaves no scar, nor is there any excess in tissue destruction beyond that which is desired. Again, since the electrodes can be adapted in size and shape to any part to be treated the method is of service to every specialist.

Each experienced operator will recall a number of conditions in his special field of operation wherein a styptic, or softening, aud at the same time a thoroughly antiseptic instrument made such by the electricity it conveys, would meet his needs better than any other and especially if it is an instrument capable of adapting itself to growths large or small, whether located upon the surface of the body or deep within the tissues.

A very important thing to be remembered by those who wish to make use of electrolysis in surgery is the directly opposite effects upon the tissues caused by the action of the anode and cathode when employed as the active electrode. The polarity must always be chosen with reference to the work to be done and the nature of the tissue to be operated on, and the success of electrolysis as an aid to surgery, is mainly dependent upon a right choice of the direction of current.

The most recent works on Electro-therapeutics have failed to emphasize sufficiently this fact—for a large per cent. of the

failures of those who have attempted to use electrolysis in surgery and who have ended by abandoning and condemning it can be traced to ignorance or neglect of the physical, chemical and physiological effects of polarity in the application.

Cataphoresis or Electric Osmosis is another of the physical effects of the direct or constant current which is already doing much to aid the surgeon and is capable of doing much more. Solutions of certain substances as cocaine, aconitia, veratria, etc., placed upon the anode or positive electrode and brought in contact with the surface of the body are, through the action of the current, made to traverse the tissues to a greater or less depth, depending upon the density and electromotive force of the current, and so bring about local medication, or even general medication if the drug is introduced in sufficient quantity and no attempt is made to prevent its entrance into the general circulation.

By this means parts of the body may be anæsthetized preparatory to surgical operations or for the relief of pain. Or remedies may be introduced into the system and made strictly local in their effects, when this is thought best, or general medication may in this manner be brought about through this means if for any reason it is made necessary or desirable.

Not only may a fluid with or without medicines dissolved in it be thus made to enter the body from without, but the capacity of a direct electric current to move the particles of fluid in the direction of the current, can be taken advantage of by the surgeon when it is desired to remove local accumulation of abnormal fluid or semi-fluid deposits or exudates—such as result from bruises, strains, inflammations, etc. The treatment, by means of the anode of a direct current, of a part thus affected, greatly assists the other agencies in its removal. Thus effusions into joints and serous cavities, swellings as a result of strains and bruises are much more readily cured if anodal cataphoresis is employed as a part of the treatment.

It is probable that what we observe as a result of the passage of a direct current through living animal tissues and

designate by the names of electrolysis and cataphoresis are not isolated phenomena, but are in reality parts of one and the same process,

It is true that both electrolysis and cataphoresis take place to some degree in animal tissues whenever they are made the part of a direct or galvanic current. And whatever changes of nutrition are brought about in the body, when such applications of electric current of this nature are made, the effects must in large measure be due to these processes. Undoubtedly other effects of the current take place at the same time which are not yet as clearly understood as these, but these are of themselves enough to explain how it is that the use of the direct current is of much service to the surgeon in many cases of perverted nutrition.

Effects on Nutrition of the galvanic or direct current is best observed in the field of surgery in modifying the condition of ulcers, such as bed-sores, varicose ulcers, lupus, etc.

Here again the choice of polarity is the first essential in bringing about the desired change. If the perverted nutrition is due to, or is attended by, an excessive fluidity as is the case in ulceration with exuberant granulations, then the application of the styptic or drying effects of the anode are indicated. If on the contrary there is an impoverished condition at the seat of disease, nutrition is feeble and there is a lack of blood serum to feed the granulations, then the process of repair would be better aided by the influence of the cathode which softens the horny margins of the ulcer and calls alkaline fluid to the part, furnishing nutriment and aiding in the removal of deleterious *debris*. Of course these local influences cannot accomplish much if unaccompanied by needed constitutional treatment, but they oftentimes furnish just that additional aid needed for effecting a cure.

It can well be seen by one who bears in mind the pathology of these states of perverted nutrition, some of them due to excess of growth in one or more elements of the tissues, while others are attended by lack of nutritive activity, that it is a matter of primary importance which pole of the current is employed in the immediate vicinity of the diseased part when

the treatment is applied—and yet this point is strangely overlooked, even by many authors and teachers who advocate this method of treatment.

What may be said for the direct current as a means for modifying nutrition in these perverted states on the surface of the body—on the skin or mucous membrane—will apply equally well when the disease is deeper seated. It has been found peculiarly serviceable in those chronic, sluggish, subacute inflammatory, swellings of the tarsus and carpus where the bones, ligaments and cartilages seem to be involved alike, interfering with function and causing but little, if any pain, but bringing about softening by degrees, and yielding so infrequently to customary methods of treatment that the patient often consents to amputation as a last resort. Here, for some reason, local nutrition has oftentimes, without any discernable constitutional cause, been diverted from its normal path and electric treatment with the direct current—the pole at the seat of disease, usually cathode—has, as we can bear witness, in a few instances at least, brought about a cure—even after amputation had been advised by competent surgeons.

A very mild current, not exceeding one-tenth of a milliampere, but applied for hours at a time, is in many of these cases more serviceable than a stronger current used for a shorter time—and this suggestion gives opportunity for the rational employment of what have been termed "body batteries," a form of electric appliance which has in the hands of the charlatan gained great notoriety of late.

Such instruments readily lend themselves to mercenary aims and are either utterly worthless or capable of doing serious damage in ignorant hands, but which have their legitimate and beneficent range of action when employed by competent and honest men.

The aids which the surgeon, whether his work be general or special, is able to secure from electricity in some of its indirect applications such as a convenient source of *heat*, *light* or *power* are more familiar to us all, but it is somewhat astonishing to us who have availed ourselves of its service and know

the value of its aid in these particulars as well, that so few who could lighten the burdens and increase the efficiency of their work by means of it as yet employ it.

The electric light can now be carried directly in to all the cavities and passages of the body that have an outlet to the surface and so give material aid to diagnosis of the conditions of these cavities and their contiguous structures. The electro-cautery is a most convenient and efficient means for applying the revulsive, destructive, curative, or antiseptic effects of heat, and is readily adapted to the requirements of the surgeon where ever this therapeutic agent is desired. Its chief advantage being that the heat can be created to any desired degree after the instrument used for applying it is accurately located at the spot to be operated on, and the amount of heat desired can then be maintained indefinitely and when its use is over the instrument may be instantly cooled *in situ* and removed cold. The advantages of such a cautery for diseased conditions within the canals and cavities of the body is too self-evident to need further comment. Many of the surgeon's instruments, such as gouges, burrs, saws, etc., need the delicate application of power for which some form of motor is useful. The electric motor is more readily adapted to these needs than any other and can be had in any form, size, or capacity desired.

For certain of these latter, of what may be termed indirect, uses of electricity, the alternating current is somewhat better suited than the constant or direct current, and as the former current is that which is coming more and more into general use for incandescent lighting, there are few who are doing surgical work, that will not be able soon, if not now, to command its service.

Sample Applications of Electrolysis to Surgery.

WILLIAM J. HERDMAN, M. D., ANN ARBOR.

It has been my privilege on several occasions to direct the attention of the members of the medical profession to what appears to me to be superior advantages possessed by the electrolytic methods over others in conserving normal tissue when the surgical removal of certain forms of abnormal growth becomes necessary. And while this method is less destructive to normal tissue than the knife it is, in suitable cases, no less efficient in removing the diseased. It is not claimed that the electrolytic method of removal is suited to every form of abnormal growth for there are certain ones such as lupus in various localities, carcinoma of the breast, leiomyoma of the uterus and osteosarcoma of the long bones, especially when they have reached any considerable size where there is no substitute for the scalpel, and there are others such as polypi of the nasal mucous membrane or of the uterus, with very slender attachments to the surface that may be as successfully, and much more promptly, removed by the scissors, the scalpel, the ecraseur or the snare. But between growths of this size and shape there remains another class composed of both benign and malignant growths which, by reason of their location mainly, but partly because of their nature, in the treatment of which the electrolytic method should be preferred. I include in this class all growths of moderate size whether malignant or benign which are so situated that the extensive removal of tissue that would be required to thoroughly extirpate them by a cutting operation would seriously damage the integrity of the part from which they grew so that its function would be impaired or its appearance marred to a much greater degree than would result if the electrolytic method was used. Such growths occur about the eyelids, nose and lips; in the nasal fossae, mouth, pharynx and larynx, and in the urethra, bladder, vagina, uterus and rectum.

As for growths upon the cutaneous surface, those occurring upon the face and neck are best suited for electrolytic treatment and chiefly because, when properly employed, it is much less likely than other methods to leave a disfiguring scar.

The main advantage of the electrolytic method when skillfully employed is that it effects destruction of the abnormal tissue and nothing else. It is capable of insinuating itself along that narrow line of demarcation between the normal and abnormal tissue, and directly destroys the vitality of certain of the abnormal cells, while the nutrition of others is cut off by the destruction of the blood and lymph channels which supply them. A gradual disintegration and absorption is the result, leaving the normal tissue in possession of the field with an opportunity to repair damages with a minimum amount of cicatricial tissue.

As the electrolytic action is applied by one or more needle points, the extent of tissue that can be acted upon at one and the same time is at the will of the operator.

If it is desired to protect the overlying skin or mucous membrane from the electrolytic action the needles can be coated, except at their points, with an insulating coat of varnish.

We have a choice of effects in electrolysis according as we make the needle used for the destructive work, the positive or negative pole of the current.

If it is the positive pole then the the action upon the tissue in immediate contact with the needle is coagulative and styptic, which is best suited for growths that are moist and vascular. If on the contrary the needle is made the negative pole of the current the action is softening and liquefying on the tissue and this is the preferable polarity for firm warty and non-vascular growths.

One great drawback in the past to the general adoption of electrolysis as a surgical procedure has been the inconveniences and annoyances that have arisen from the appliances for furnishing a direct or galvanic current. All forms of primary or secondary batteries require more time and attention,

not to say special knowledge, than the busy surgeon can devote to them.

But with the industrial currents of this nature now at every door and with most admirable apparatus for conveniently modifying and controlling them for this purpose, these difficulties, which formerly stood in the surgeon's way who otherwise might wish to employ electrolysis, are now entirely overcome.

I have selected from my clinical experience two illustrative cures, chosen from among many, first because the locality of the disease in each case is one which offers peculiar difficulties to surgical operation, and second, because the diseases dealt with are those which usually require the most radical surgical measures for their removal in order that the possibility of recurrence *in situ* may be prevented.

Myeloma of the Superior Maxillary Bone.—The patient G. P. of Howell, Mich., farmer, age 56, of good habits.

Three years ago he first noticed a small growth in the roof of his mouth, which grew rapidly, until it was one and one-half inches long, an inch and a quarter wide and protruded downward against the tongue, so that for some months previous to his coming to see me the patient was unable to close his mouth. At the time I saw him, December '96, the growth gave all the clinical evidence of a myeloma. The patient was anaemic, haggard, had lost flesh and was living on liquid food, as he was unable to close his jaws to masticate. The case was one which ordinarily would have been subjected to extirpation by the knife.

But as that method would have required, as is well known, a somewhat formidable operation involving anæsthesia, considerable loss of blood, some hazard of shock in his feeble health, and would in all probability have resulted in serious deformity of the mouth, nasal fossae and pharynx, I suggested to him and to his son who accompanied him, that he submit to the electrolytic method of treatment which I thought would at least arrest the further progress of the growth and perhaps effect disintegration and cause it to disappear. To this proposal he consented, and at intervals of two or three weeks, beginning about December 1st, '96, I gave him in all seven treatments, making the needle the positive pole of the current because the tumor was exceedingly vascular. The needle was first introduced at the margin of the growth near its junction with healthful tissue and, as nearly as I could judge, at the entrance of the feeding vessels. Only four or five introductions of the needle were made at each sitting, and as the

shrinking from the margins became evident the needle was at later treatments plunged into the centre of the growth sometimes to the depth of three-quarters of an inch or more at such points as vascularity and cell proliferation seemed to be greatest.

The interval between treatments seemed to be long enough for the normal tissue to recover its control and get rid of the disintegrated tissue, and a steady diminution of the growth was noticed after the third or fourth application.

From that time without any untoward results the growth has gradually decreased until the surface has now resumed almost its normal level. The patient has recovered his health and strength, and never, as the result of the treatment was he incapacitated for an hour *

Electrolysis of Rectal Neoplasms.—Many of us have been and will be called upon to deal with abnormal growths in the rectum, malignant or benign. These may have been of the nature of epithelioma, carcinoma, polypoid, villous or hemorrhoids. If malignant, the disease may have progressed so far that a choice of method of operation is no longer afforded, resection offering the only hope of relief. But let us presume that the growth, if malignant in nature, has been discovered early, and it is still confined to a limited area of the rectal wall or that it is benign in character with no tendency to progress or disseminate itself into the adjoining tissues. It may be that it is located high up in the rectal pouch; that its origin sinks deep between folds of normal mucous membrane; that it is extremely vascular. Such are the conditions which attend not infrequently the early stages of epithelioma, the most frequently occurring form of malignant growth that is found in this locality. The difficulties that beset one in the attempt to get at and successfully remove such growths are oftentimes insurmountable without a free posterior incision through the rectal wall, requiring the temporary, if not permanent sacrifice of the sphincters and perhaps the removal of the coccyx. But good surgery aims to accomplish its end by checking the abnormal with the least possible damage to the normal and just in proportion as it succeeds in this does the science of

*NOTE.—This patient was shown to the members of the surgical section of the Michigan State Med. Soc., at the meeting in Grand Rapids, May '97, and the successful result was made evident to many competent witnesses.

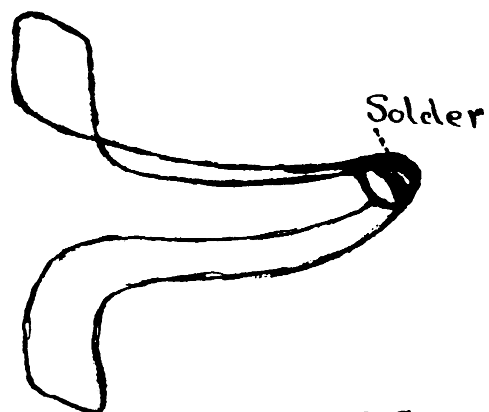
surgery progress. Such growths are often broad at the base; they are not infrequently extremely vascular, fed by large vessels freely anastomosing; their origin may be inaccessible to knife or ligature by reason of intervening folds of normal mucous membrane; they oftentimes are remote from the surface preventing the operator from using any form of cutting instrument easily and when he attempts this the profuse hemorrhage hides everything from sight; the incision must include a wide margin of normal tissue about the base of the growth, if it be malignant, to preclude the possibility of return so likewise must the ligature, to be effectual, embrace all that is abnormal and more; the resulting cicatrix from these methods is likely, therefore, to cause stricture or adhesions that seriously impair the function of the gut.

Anodal electrolysis brought about at the base of such a growth through the agency of an insulated needle and a regulated constant current successfully overcomes all these difficulties. The blood vessels that nourish the growth are destroyed by coagulation and shriveling of the tissues at the point where they enter it. No hemorrhage obstructs the view and there need be no loss of normal tissue. There is no danger from secondary hemorrhage; no raw surfaces to favor septic infection; no stitches to remove; no ligatures to slough away. The patient in many instances need not be confined to bed a day and in but few cases this method of operating requires the use of an anæsthetic. In this statement of fact you will recognize advantages in this method of procedure over any and all others which need but to be mentioned to be appreciated.

Before relating my experience with the case selected, I wish to offer a suggestion which I think that those who have had much experience in the surgery of the rectum will recognize as worthy of general adoption in suitable cases.

It relates to a method for exposing the rectal walls by means of a wire speculum and the lithotomy position. For this idea I am chiefly indebted to my friend, Mr. Richard Davy, of Westminster College, London, in whose clinic I first saw it applied. The advantages of this speculum over any other in use are at once apparent. Its shape makes it a

wedge-shaped dilator of the sphincters as it is gently pressed into the anus. When in place it obscures but little of the rectal surfaces. By its shape it is self-retained, and can be readily made more so by a tape carried from its projections to a waist band. It therefore requires no assistant to hold it in place and gives free space about the orifice for sight and operation. And last, but by no means least, it permits a wad of cotton or sponge to be placed at its apex to remain there undisturbed by the most violent peristaltic action of the bowels and successfully prevents the discharges from reaching and obscuring the seat of the operation. With this instrument in



Spring Wire Rectal Speculum

place and the patient in the lithotomy position, the perplexities that so commonly excite unholy emotions in the mind of the operator when attempting to place a stitch or find the mouth of a bleeding vessel in this locality are heard of no more.

Epithelioma of the Rectum.—Miss J. D., age 24, consulted me for obstinate constipation and frequent hemorrhages from the bowels, presumably due to internal piles. Examination disclosed a soft vascular mass, two inches in diameter, with a somewhat constricted base on the posterior rectal wall, its lower margin fully two inches above the upper margin of the internal sphincter. The mucous membrane formed a fold across below the growth so that it was difficult to expose the margin of the growth at its base. At this time I decided to remove the growth by transfixion and the double ligature. The patient was anæsthetized and the operation with difficulty, but successfully performed, although the hemorrhage

was frightful and it was two weeks before the ligatures all came away and the part was sufficiently healed to permit the patient to leave her bed. In three months the growth had returned almost as large as before. I then determined to try anodal electrolysis as I had all the facilities for it and it could not be attended by such alarming hemorrhage. Again the patient was anæsthetized, placed on the operating chair in the lithotomy position and the wire speculum in place. The base of the tumor was easily reached by a long stout curved needle held in an electrode needle holder and the base of the growth was pierced in half a dozen directions while a current of about six ma., with the needle as the anode was passed for a period, in all, of 12 to 15 minutes until the tissue at the base was pretty thoroughly coagulated at a number of points. The patient walked away from the office within an hour after the operation, returned in a month for examination at which I and others failed to discover the least evidence that such a growth had ever been present, the mucous membrane appeared entirely normal, there was no contraction; the rectum was acting properly, and has continued to do so ever since, now three years.

I have made use of these illustrations of the application of electrolysis in surgery because they serve to present in the most striking manner the chief features of its superiority. My purpose will, however, be but half accomplished if your thoughts are confined to this one application and you fail to recognize the broad generalization of these phenomena of electrolysis to a multitude of disorders requiring surgical interference. The coagulating, astringent, drying effects of positive electrolysis and the possibility of conveying these effects through the tip of a needle to deep-seated parts without marring the overlying tissues, give to general surgery a ready means of controlling abnormal vascular dilatations such as aneurism, nævi and varicosities without the necessity for a surface wound or elaborate antiseptic precautions, while the gynecologist, in the vascular fungoid and polypoid disorders of the endometrium would find it, as some have already done, a prompt and sufficient means of cure; the ophthalmologist, the rhinologist, the laryngologist, the aurist, and the dermatologist will each see that it has adaptation to many conditions that arise in the range of disorders peculiar to the tissues dealt with by each of them superior to methods of treatment now in vogue.

But our illustration has dealt solely, thus far, with the range of efficiency peculiar to *anodal electrolysis*, or the effects that can be brought about in living tissues by means of the *positive electrode* of a continuous current. *Cathodal electrolysis* is capable of proving none the less serviceable to surgery. In the field of conservative surgery I am convinced it is yet destined to play a very important rôle. Cicatricial tissue, the result of inflammatory action, is responsible for much human misery. It narrows, and occludes and distorts many of the channels of the body. The nasal duct, the Eustachian tube, the œsophagus, the urethra and the cervical canal of the uterus are conspicuous as points where stricture due to this cause are of frequent occurrence. In dealing with such strictures our methods and results are, as a rule, far from what we desire. Conservative surgery as has been said, aims to remove the abnormal with the least possible injury to the normal, but in the majority of measures now employed for the removal of stricture the normal is made to suffer with the abnormal and the result is proportionately unsatisfactory. It is my belief, after some personal experience in its practice, together with a careful review of the testimony of those more experienced, that *cathodal electrolysis* has the effect, when skillfully managed, of relaxing, softening and disintegrating these bands of cicatricial tissue and this without damage to normal tissue adjacent to them, thus releasing the canal which they have narrowed from their obstructing clutch. If this is true (and if it is not already demonstrated to be true, none of us need be long in ignorance of the facts) you can readily see what an important stride will be made in conservative surgery as soon as *cathodal electrolysis* is universally employed for the removal of strictures, pelvic adhesions, fibroid tumors and the like, which at present give rise to some of the most formidable and fatal operations known to surgery.

Notes.

Treatment of Strictures of the Urethra by Electrolysis.—Electrolysis of the urethra for the cure of strictures was first practiced with success by Tripier and Mallez in 1863, so that it is not the new operation some claim.

Since its first use a number of improvements in the urethral electrode, and operatory technique have been made until we have the following rules announced three years ago by Gautier at the Congress of the American Association at Chicago.

The electrolyser is a rubber or catgut urethral bougie whose diameter varies according to the case to be treated, for it can be made of all models for the treatment of accessible strictures, œsophageal, urethral, lachrymal or rectal.

This bougie is divided 6 cm. from its vesical extremity and the two cut ends are screwed into a socket of platinum about 1½ cm. long, and of a diameter slightly greater than that of the bougie. This socket is joined to the negative pole of the battery by a flexible wire which was fixed in the interior of the bougie when it was made.

The introduction of this bougie is easy and made without violence, it causes no pain, accommodates itself to the curves of the canal which it does not irritate and permits a slow, gradual dilatation which little by little changes and modifies the vitality of the parts and protects the patient from false passages, retention of urine, and laceration of the urethra.

OPERATORY METHOD.

1st. In the first place explore with a bougie the situation, nature, and especially the lumen of the stricture.

2nd. Inject into the bladder one-half a litre and more of a boric acid solution.

3rd. Chose an electrolyser of the same diameter as the exploring bougie.

DURATION, INTENSITY AND NATURE OF OPERATION.

The electrolyser is joined to the negative pole of the battery, the positive pole represented by a plate about 18 x 12

cm. covered with amadou and chamois, is placed on the abdomen or thigh. When the metallic socket of the bougie touches the strictured part of the urethra the current should slowly be increased to 10, 15 or 20 ma. From this time, without any violence, the instrument is introduced, till it penetrates to the bladder. If the stricture is long and firm it will take 10 minutes, even a quarter of an hour with an intensity of 12 to 15 ma.

If the strictures are multiple and of unequal dimension it will be necessary to commence by electrolyzing the narrowest stricture. After the sitting, the electrolyser is withdrawn and the patient empties the bladder. Thus the antisepsis of the urethra is insured. It is harmful to catheterize immediately with a bougie of large caliber. The next day, or every other day for a week a sound of larger size each time may be passed, which may be used also to inject into the bladder a boric solution.

A second and even a third sitting may be necessary, if the strictures are narrow and numerous, for with this electrolyser the dilatation is gradual. An interval of ten days between each electrolysis is necessary.

This procedure is recommended because it is efficacious, painless and inoffensive.

Dr. Robert Newman of New York City has had, perhaps, more prolonged and extensive experience in this method of treating urethral strictures than any other, living or dead. He has employed electrolysis for the cure of urethral strictures for nearly thirty years.

He says of it: "The theory of electrolysis is based on sound scientific principles, it causes a galvano-chemic absorption of the stricture through the mucous and sub-mucous tissues by the direct action of the negative pole with weak currents of from 3-5 ma.

To succeed with electrolysis in urethral stricture, the operator must be a good physico and physiologic electrician as well as a genito-urinary surgeon.

If some do not succeed with electrolysis that proves nothing else than the individual failure, which may de due to the operator, false diagnosis, to faulty instruments, and such failures or negative results do not invalidate the records of successes, all perhaps due to ignorance.

The principal points in managing urethral strictures are: a correct diagnosis, gentle handling, causing no pain; and for the operation of electrolysis, a galvanic battery, good electrodes, the negative electrode used to the stricture, weak currents, 3–5 milliamperes, long intervals, using only one instrument at a séance and never to operate while the parts are in a state of acute inflammation.

Coagulations of Aneurisms.—Since Ciniselli introduced volta puncture as a cure for aneurisms good results have been obtained from its use.

The method of application to-day after passing through various hands and being somewhat modified each time, consists in an introduction of the positive electrode, a needle, into the aneurism, the negative, in this case, the dispersing electrode, a broad plate, being placed at some indifferent point. At the positive pole there is a preliminary electrolysis by which acid is liberated, and this coagulates the albumin of the blood whence we have the formation of the clot. Opinions differ as to the necessary number and the duration of sittings, some authorities giving continuous treatments, others alternating them by a period of rest.

Volta puncture has given good results in cases of external aneurisms, and even in thoracic aortic aneurisms.

Its general value is well established.

Lessons in Electrotherapy—Tripier.

VOLUME IV. OCTOBER, 1897. NUMBER 4.

BULLETIN

OF THE

ELECTRO-THERAPEUTICAL LABORATORY

OF THE

UNIVERSITY OF MICHIGAN.

Published Quarterly by The Inland Press, Ann Arbor, Mich.
Subscription Price, One Dollar a Year.

Relation of Magnetism to Living Organism.

Vegetable organisms, animal organisms, all animate as well as inanimate things react in some manner to the several forms of energy known to us. Mechanical energy, radiant energy, (light), chemical energy, vibratory energy, (heat), electric energy each produces its effects upon matter organized or unorganized, living or dead, and in the process of action these several forms of energy are often transformed, the one into the other.

The intimate relationship existing between electricity and magnetism, the inseparableness of their phenomena makes it more than probable that when electric energy is operating magnetic stress must be credited with a portion of the work accomplished, and *vice versa*. Whenever a current of electricity traverses an animal body in any direction the magnetic field resulting from the passage of the current and surrounding its path must disturb in some manner the molecular and atomic activities that are going on within its range in the tissues and fluids through which the current of electricity

passes. The amount of this disturbance will depend upon the strength and character of the magnetic stress which makes up this field or, in other words, upon the strength and nature of the electric current.

A constant uni-directional current will create a magnetic field of constant polarity and of uniform tension. A uni-directional current, but of varying strength, will create a corresponding magnetic field, pulsating or varying in intensity. While an alternating current will be attended by a magnetic field alternating in polarity with a frequency corresponding to the alternations of the electric current and of an intensity varying in degree with the strength of that current.

We have found that the most noticeable physiological response to an electric current obtained from living animals is that resulting from sudden and wide differences of potential. We would naturally expect, therefore, that a magnetic field with rapidly reversing polarity and sudden variations in its intensity would produce more noticeable results in a living organism than would a more uniform or constant field.

Careful scientific observation and record of the relation of magnetic stress to physiological action, either in vegetable or animal structure, separate from the effects produced by the passage of the current of electricity itself has been attempted by few. What has been done so far has led to contradictory conclusions. Experiments have for some time been carried on in this laboratory with the view of gaining some exact knowledge of the amount of change in ordinary life processes that can be brought about by the modifying influences of various forms of magnetic stress.

In order that the reader may be able to trace with some degree of probability the relationship of cause and effect in these experiments I have requested my friend, A. E. Dolbear, Professor of Physics in Tufft's College, Massachusetts, to favor the BULLETIN with a short article on the relation of electricity and magnetism to molecular and atomic phenomena.

W. J. H.

Molecular Effects of Electricity and Magnetism.

PROF. A. E. DOLBEAR, TUFFT'S COLLEGE, MASS.

In any attempt to interpret phenomena involving matter and energy one needs to start with a tolerably fair idea of the nature of molecules and the changes that are possible among them. There are about seventy different kinds of matter called the elements and these consist of atoms which combine in definite ways to form molecules. The definite combinations result from what has been hitherto called chemical affinity but which we now know to be altogether conditioned by temperature. At high temperatures all molecules are dissociated from their atomic components and at low temperature chemical combinations will not take place. When there are not two kinds of atoms present which can combine the atoms combine with each other so that at ordinary temperatures the molecules consist of two similar atoms as of H–H, O--O, etc.

Under ordinary circumstances when there is a combination of atoms to form molecules there is generated a quantity of heat. Thus if 1 gram of hydrogen with oxygen in the nascent state unite, they yield 54000 calories. If they are in the ordinary gaseous state they yield on combustion but 34000 calories, hence there is represented an amount of energy equal to 20000 calories due to the combinations of similar atoms with each other, and this amount of energy has to be spent upon the molecules of hydrogen in order to reduce them to the atomic state. This large amount of energy is needful only for molecules consisting of only two or three atoms. In general the larger the number of atoms in a molecule the less stable it is, the less energy in the shape of heat or otherwise is needful to decompose it or to rearrange its constituents into other molecular forms.

How exceedingly complicated molecules may be has not been known until within very recent years. A molecule of a hydrate of $Ca\ Cl_2$ may contain 4500 atoms. One of gum

gum arabic about 6000. Egg albumen has nearly 30000, while protoplasmic colloids have more than 30000 atoms, and how unstable these are is patent to all, relatively slight changes in temperature, presence of oxygen, of ferments, etc., rapidly reducing them to simpler molecular forms.

It ought to be borne in mind that the properties of a molecule depend upon the arrangement of the atoms which compose it as much as they do upon the kind of matter and especially is this true in so called organic substances which are made up of but a few of the elements, mostly of carbon, hydrogen, oxygen, starch and cellulose and since they have the same identical chemical composition, they can differ only in atomic arrangement.

The processes of the chemical laboratory give to us a multitude of artificial organic compounds and the employment of electrical currents in chemical industries gives evidence that all sorts of reactions can be produced by its agency. This kind of work began with decompositions and the separation of the alkaline metals. It next was employed in electroplating, and now many chemical substances are produced on a commercial scale and the art is rapidly advancing.

All this is possible because electricity facilitates atomic exchanges.

It is not so difficult now to understand how this comes about as it was not long ago because we have a glimpse of the nature of the activity. There is first what we term a magnetic field wherever there is an electric current and the field reacts upon everything in it in a way typified by the behavior of a magnet in the same field. It has its axis twisted into a new position to correspond with the axis of the current. If the body thus acted upon be a solid body and its molecules quickly absorb such stress, like the metals, the whole body will move and we call the action inductive. If the substance be conductive in a degree and in a liquid state so cohesion is slight the individual molecules are independently moved into new positions, rotated.

When the substance is dissolved in a liquid, like copper in sulphuric acid, one must now consider that the molecules of

copper sulphate are not the stable things they are in the dry state. There are the best of reasons for thinking that not only the copper but the sulphur, the oxygen and all the rest are continually exchanging partners. Chemical cohesion is greatly reduced in the liquid and when the current of electricity is sent through it, the magnetic field gives direction to every atom in it, pushing the copper, the hydrogen or atoms of similar property in one direction and the rest in the opposite and making possible chemical actions which otherwise could not take place. It also furnishes energy for doing the work. The energy of a current is proportional to the square of its strength. For this reason chemical actions can take place which require energy to produce them, and instead of giving up energy in the shape of heat, the molecules themselves may become loaded with energy. This is really what takes place when water is decomposed. The gases are loaded with an enormous amount of energy which they have got from the electrical current. This kind of action is not limited to a chemical tank, it takes place wherever an electric current provides the necessary field.

What can be done by a current through an animal body we know in many cases by the external signs. Acid and alkaline reaction upon the skin at opposite terminals, osmosis, etc., such as take place in inorganic or non-living things, but within the body where the current flows or where the magnetic field can affect it, there is no reason for supposing the electric reactions to be different in kind from what they would be elsewhere.

Those chemical changes in the body which are called metabolic must as certainly be produced when a current of electricity is sent through it as when it is absent.

Almost everything now known about electro-magnetism seems to imply that a magnetic field, whether produced by a permanent magnet or by a current, reacts in some measure upon all kinds of matter within the field and in such a manner as to rotate in some degree every molecule so as to make it assume a different position from what it would assume if not thus acted on.

If chemical action is taking place in that field more energy must be spent then for a given product. In the process of digestion the molecular structure is quite broken down into its atomic constituents which again recombine into radically different compounds.

An electric current or a magnetic field ought to make a difference both in the rate of reorganization and the product. Just what this difference would be might be difficult to make out on account of the complexity of the process. In the products of respiration and in the other excretions I would expect this effect might be detected. I should expect that oxidation would take place at a more rapid rate in a quiet magnetic field, for it is now certain that oxygen displaces nitrogen to an appreciable extent near the poles of a magnet. In such case the magnetic field should act as a stimulant.

If the magnetic field were an alternating one there would be still more energy spent, not that it would do chemical work itself but would accentuate it.

If the organic mechanism be weak the process ought to be materially helped by electrical agency of the proper sort and amount, conditions which of course can only be determined by experience. Anything which can relieve the impaired system of the stress of duty in digestion or assimilation is needed greatly, and theoretically there is nothing known that can approach electricity applied either as a current through the body or inductively in a magnetic field, steady or alternating, for it is certain as anything can well be that every molecule in the circulatory system or where chemical action is going on within the body, is made by it to change its position and rate of motion. Atomic cohesion is lessened so that less energy is required to completely decompose the molecules, and if the transforming mechanism be intact its functions are performed with less friction and loss.

The Influence of Magnetic Stress on Physiological Action.

PROF. WM. J. HERDMAN, DIRECTOR OF THE LABORATORY.

Further argument or exposition than that so clearly presented in the foregoing paper is needless to convince us that there exists the possibility of a relationship between magnetic energy and physiological or life processes which is deserving of careful investigation. Reasonable hopes can be entertained that from such explorations much will be discovered that will be useful in therapeutics. The interdependent and interchangeable relations of magnetic and electric energy are already well known. The interchangeableness of electric and physiological energies are likewise readily demonstrable.

Radiant energy, mechanical energy, chemical energy, each have their physiological equivalent, and it is wholly unwarranted to assume that magnetic energy alone sustains no relationship to or has no influential disturbing action upon the molecules and atoms that make up a living animal or vegetable organism. The opinion has long been entertained by many that magnetism has its part to play in these life processes and some few efforts have been made in the line of direct experimentation by competent men to discover, if possible, some facts which would justify this opinion. Notable among these are the experiments reported by Kennelly and Peterson at the New York meeting of the American Electrotherapeutic Association in 1892.

In one series these experiments consisted of observations as to the behavior of a drop of water, pulverized iron (iron by hydrogen), powdered hemoglobin, living ciliated epithelium, and the circulation of blood as shown in a frog-foot-preparation, placed on a microscope stage and inserted between the poles of a powerful electro-magnet. The drop of water was seen to change its shape in the magnetic field and the finely divided iron acted in the same manner as iron filings but the results upon the other substances were reported as negative.

A second series of experiments sought to determine the effects, if any, upon motor nerve conductivity by enclosing a small dog for some hours in a strong magnetic field. This experiment as reported appears to me to be incomplete and therefore valueless.

A third series had in view to determine the effects upon either sensation, motion or other physiological action by inserting the head of the subject for an indefinite, but presumably brief, period into the field of a strong electro-magnet through which the exciting current was made and broken without the knowledge of the subject of the experiment. The subject's statement was taken as to his state of consciousness during the test and sphygmographic tracings were made of the pulse at the wrist and the rapidity of respirations was noted. These experiments likewise resulted negatively.

A final series was made with the view of testing the effect of a rapid reversal of the magnetic field. This was done by using a great number of turns of copper wire in the form of a coil of sufficient diameter to admit the head of the subject into its interior and so subject the brain to the alternating magnetic field for a length of time not stated.

The authors of this valuable paper conclude their account of these various experiments with the following statement: "The human organism is in no wise apparently affected by the most powerful magnets known to modern science; neither direct nor reversed magnetism exerts any perceptible influence upon the iron contained in the blood, upon the circulation, upon ciliary or protoplasmic movements, upon sensory or motor nerves or upon the brain."

It is true that the results obtained by them were for the most part negative and we cannot deny that their experiments were in the main carefully devised and faithfully carried out. But negative results are themselves positive facts which serve to mark the limitations in this special field of science. The first clippings from the marble block may not reveal the statue that lies concealed within, and yet when the blows on the chisel are intelligently and skilfully directed they make positive progress toward that end.

I think it will be seen upon careful scrutiny that the claims made in the conclusions drawn from these experiments by their authors are entirely too broad, and that the means which they employed for detecting possible changes in the physiological mechanism left much undone.

It may be true that the most powerful magnetic flux that man can devise is incapable of producing changes in certain substances, such as hemoglobin, of a nature that will be revealed on the stage of a microscope. It may be likewise true that neither varying uni-directional nor alternating magnetic fluxes may cause such changes in the brain action, at least in a brief period of time, as will visibly disturb its functions. Yet in spite of this, such molecular action as is going on in living cells may be, and in all probability is, modified by variations in the degree and direction of magnetic stress when such molecules are subjected to it, and it will need only patience and shrewd guessing as to where to look for the results of such action in order to detect them.

Permit me here to make a brief quotation from a recent work of Prof. Dolbear: *

"It is customary to think of iron as being peculiarily endowed with magnetic quality, but all kinds of matter possess it in some degree. Wood, stone, paper, oats, sulphur and all the rest, are attracted by a magnet and will stick to it if the magnet be a strong one. Whether a piece of iron itself exhibits the property depends upon its temperature; for near 700 degrees it becomes as magnetically indifferent as a piece of copper at ordinary temperature. Oxygen, too, at 200 degrees adheres to a magnet like iron.

"In this as in so many other particulars, the manner in which a piece of matter behaves depends upon its temperature; not that the essential qualities are modified in any degree, but temperature interferes with atomic arrangement and aggregation, and so disguises their phenomena. As every kind of matter is thus affected by a magnet, the manifestations differing but in degree, it follows that all kinds of atoms, all the elements, are magnetic; this is an inherent property in

* Modes of Motion, A. E. Dolbear; Lee & Shepard, Boston. 1897.

them as much so as gravitation or inertia, a quality, apparently, depending upon the structure of the atoms themselves in the same sense as gravitation is thus dependent, as it is not a quality of the ether. An atom, then, must be thought of as having polarity, different qualities on the two sides, and possessing a magnetic field as extensive as space itself."

If this is the true conception of every atom in its relation to magnetism no matter into what combination it enters, we cannot arbitrarily divorce the atoms of matter which enter into living vegetable and animal cells from such magnetic attributes any more than when they are present in non-living substances, and such anatomical magnets would be subject according to their nature to the influences of varying magnetic stress no matter into what combinations they had entered. But the results of such stress upon these atoms and molecules would of course be modified by the other forces operating upon them at the time and in the situation where they are placed. What those results are can be determined only by observation and experiment. It is scarcely to be expected that they would be apparent to the naked eye or, being molecular, that any power of the microscope would reveal them. Seeing also that every organism on the face of the earth has, from the beginning of its existence, been bathed in and permeated by magnetic flux due to the earth's magnetism, and that in all probability the number of lines of magnetic force that traverse the body of a man bathed in this earth magnetic field are seldom constant, such influences as they exert are so much a part of the constant existence of the organism and so continually operating that they are no more likely, but even less likely, to be the subject of conscious perception than is the oxidation of the blood or any other of the tissue processes that are continually going on in our bodies, but of which we are unconscious.

A marked variation, however, in strength or quantity of such influences as are constantly operating upon the organism may be presumed to exhibit in time, longer or shorter, some modification in the action of that organism. Thus we note the influence of change of climate upon the growth of

both plants and animals where the variable factors are those of degrees of moisture, atmospheric pressure, heat and sunlight. All of which are in operation continually in all places on the face of the earth, but vary in proportion in different localities, and so cause the results depending on them to vary correspondingly. Just as the variation in one or other of these factors which enter into what we designate as climate affects the physiological activities of animals and plants so, it appears to me, might we expect some changes to be brought about by artificial variation in the magnetic field, provided such change is strong enough and is continued long enough to show some result.

Experiments With Magnetic Fields.

Guided by such considerations as have been presented in the preceding articles a series of experiments was commenced more than two years ago in this laboratory upon man and growing animals by subjecting them for a considerable length of time to the influence of alternating magnetic fields.

This was done by constructing a solenoid three feet in diameter, of number 10 underwriters wire, and with a sufficient number of turns so that a current strength of five amperes produced an average of sixty-five C. G. S. lines for each square inch of space in a plane cross-secting the space within the coil. Both for convenience and to determine the value of what we already have at hand, I used the current from a Thompson & Houston alternating dynamo employed for electric lighting, to excite the coil, or solenoid. This dynamo makes 124 cycles per second or 248 alternations. So that the magnetic field or stress in the space enclosed by the coil changed its polarity with this frequency. Whatever occupied this space therefore was subjected to this rapidly reversing and varying magnetic stress.

The first series of experiments was made with the view of determining the influence of this magnetic field on the metabolism of tissue as determined by the output of urea. Three subjects were chosen. Two of them healthy young

men, students of medicine, and the other a man of thirty-eight years of age who had for two years been suffering from paralysis agitans, but who, aside from this nervous affection, was in fair health. The diet was regulated in amount and variety in each case for a week previous to subjecting them to the magnetic action, and a daily estimate was made of the amount of urea excreted. Then for a week's time without change of diet or manner of living in any other respect each one of the three subjects was placed within the solenoid, comfortably outstretched upon a platform, and remained there for two hours each day their bodies pervaded by the alternating magnetic stress of the average strength above mentioned. During this week also a daily estimate of the quantity of urea was made, and it was found that in all three cases there was a daily increase of about 10 per cent. in the amount eliminated during the period in which the subject was in the magnetic field. No other effects were noticed that could be detected by this method of observation. There was no apparent change in the depth or frequency of respirations nor in the strength nor frequency of the pulse or arterial tension. Though it is possible that had more delicate or exact methods of testing for such changes than the unaided eye and touch been employed, some difference in these functions would have been observed. The subjects were conscious of no change in sensation or motive power except that the patient with paralysis agitans claimed that the period spent within the coil had a soothing and quieting effect upon him and that the muscular tremor which attended his disease was for several hours after each exposure much less violent.

The next series of experiments was with growing animals to determine the effect, if any, of the alternating magnetic stress in retarding or accelerating their growth. Experiments of this nature I have carried on at the laboratory almost continuously for the past two years. Some of the time the animals used were rabbits and at other times guinea pigs. As soon as one or more litters of young rabbits or guinea pigs were old enough to be separated from their mothers, they were divided into two bunches as nearly alike in age and weight

as possible, and were carefully weighed. The two bunches were placed in conditions of living in all respects similar except that from five o'clock in the evening until midnight one bunch was placed in a cage (Fig. 1) made of the kind of wire above mentioned through which an alternating five ampere current with the frequency of alternations above mentioned was passing, and the other bunch was placed in an exactly similar coil which was not connected with the current circuit. This plan was pursued with each group of animals selected until they had reached their full growth, or from six to twelve weeks, according to the age of the animals at the commencement of the experiment. The laboratory notes

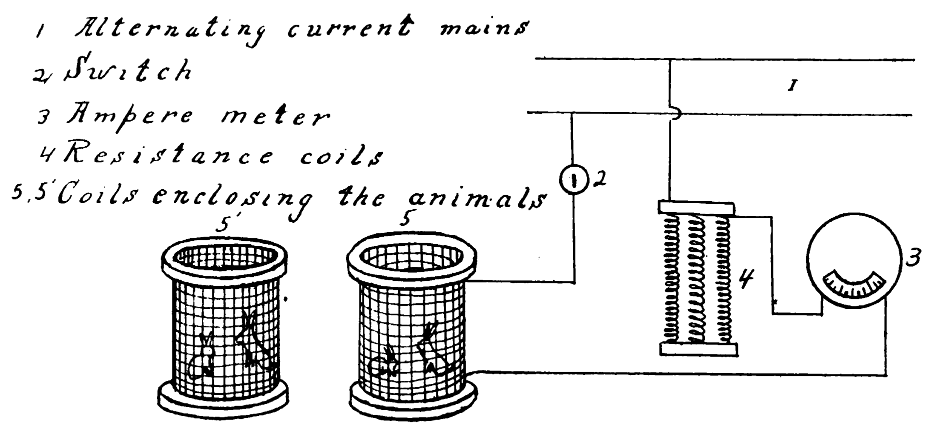


FIG. 1.

contain the weekly record of the weight of each of the groups of animals experimented upon in this manner, but it does not seem necessary to burden this paper with the details. The interesting conclusion that has been reached so far from these experiments, which are still in progress, is that the group of animals immersed in the alternating magnetic field without exception began, after the first week, to outstrip the other group in weight, and a gain of from eighteen to twenty-four per cent. in favor of the animals within the magnetic field was observed each succeeding week until they neared the period of full development, at which time the weekly gain was less. During the two years in which these experiments have been going on, ten separate groups of animals have been used either in the field or as controls, each group containing from

three to five animals, and uniformly those placed in the magnetic field gave evidence for the first few weeks of accelerated nutritive action. In the case of two groups when the experiment was continued beyond eight weeks the curve of increase shown by the magnetized animals, which until eight weeks ran 20 per. cent. higher than that of the other group, gradually declined and at the end of the twelfth week their weight had fallen a little below that of the other group.

It is an interesting fact that the janitor who has charge of these animals and who is a shrewd observer, but without knowledge as to the purpose of the experiment, called my attention to the fact that the group of animals that was placed within the magnetic field spent much more time in sleep during the day time, that is when the current was withdrawn, than did the other group, but in no other respect except the increase in weight did he nor I notice any difference in their appearance or conduct.

As far as these experiments go they appear to show that alternating magnetic stress is in some way related to a quickened metabolism of tissue; that magnetic energy goes through some transformation and appears as physiological energy.

These results are very similar to those reported by d'Arsonval and others as resulting from what that observer has termed auto-conduction brought about by high-tension high frequency currents and as the apparatus employed by d'Arsonval is not unlike that which I have employed in my experiments, although I did not see any description of d'Arsonval's experiments until some months after I had begun those I have been describing, it is not improbable the effects we have observed are due to the same cause. There is this difference to be noted, however, that while the currents employed by D'Arsonval were of the high-potential and high-frequency character, the current employed by me was of only 52 volt pressure and the frequency of alternations but 248 per second.

W. J. H.

Notes.

The Disintegration of Tissues—Physiological effects of high tension discharges on organic structures.—Among the numerous applications which have been tried for the treatment and cure of diseases, there are few which have given as much hope as the destruction of malign tumors by means of electric discharges.

Final conclusions have not yet been reached, but some interesting experiments lately made by J. Inglis Parsons show that considerable progress has been made in this direction. Parsons after many years holds the opinion that electricity has its rôle when the bistoury can do nothing further and the disease has returned.

Parsons' important discovery described here is that the organic tissue can be disintegrated throughout the course of a current without appreciable heat or caustic action by the use of discharges from an induction coil.

In 1888 he discovered that the effect of the constant current applied to fibrous tumors was limited to the small surface surrounding the poles, and that the destruction produced here was greater than necessary.

It then seemed preferable to attempt to use the destructive effect of a sudden discharge, and he made a trial by suddenly applying the current of a powerful voltaic battery. The success was only partial, and the experiment led him to believe that the discharge from a strong induction coil with the feeblest possible resistance in the secondary would probably give him a better result.

The coil used was one worked by hand, having a resistance in the secondary one-seventh that of the ordinary coil, giving the same length spark.

Dr. Parsons' idea in reducing the resistance of the secondary coil from 7,000 to 1,000 ohms was to concentrate in the tumor the greatest proportion of the total electric energy developed in the secondary circuit.

The resistance of a tumor being from 100 to 250 ohms,

a very small part of the total energy developed in the secondary circuit of 7,000 ohms would be developed in the tissue.

Dr. Parsons' experiments were made by the introduction of platinum needles into pieces of beef, the particles of which were examined microscopically before and after the discharge from the coil.

It was noted that the muscular fibres were completely disintegrated in an ellipsoidal space between the two poles, the destruction being less in the axis of the ellipse than nearer the surface, due to the well-known tendency of variably rapid currents to pass to the circumference of their conductors.

These experiments showed that the effects of successive discharges might be accumulated so that if one discharge was too feeble to produce disintegration with a single application, repeated applications of the same discharge would produce an excellent result.

Dr. Parsons believes that tension is of more importance than the current in producing these disintegrating effects. In this case it is a question whether decreasing the resistance of the secondary is advantageous.

A reduction of the resistance of the secondary coil would retard the energy of the current, and consequently the tissues would not be subjected to so great a difference of potential, as by a secondary current of higher resistance. Parsons seems to support this point by an experiment in which he had a Leyden jar in the circuit. Here the current increased more rapidly, and the disintegration was excessive although limited almost completely to the point surrounding the poles.

More exact measures are necessary to determine the true electric conditions, as current and tension, to produce the most satisfactory results.

2nd Copy